

NSF AUTHORIZATION AND INDUSTRIAL COMPETITIVENESS

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND
SPACE

OF THE

COMMITTEE ON COMMERCE,
SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDREDTH CONGRESS

FIRST SESSION

ON

AUTHORIZATION OF THE NATIONAL SCIENCE FOUNDATION AND
INDUSTRIAL COMPETITIVENESS

MAY 28, 1987

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THURSDAY, MAY 28, 1987

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:37 a.m., in room SR-253, Russell Senate Office Building, Hon. John F. Kerry presiding.

Staff members assigned to this hearing: Pat Windham, professional staff member and Mark Farrell, minority professional staff member.

OPENING STATEMENT BY SENATOR KERRY

Senator KERRY. This hearing will come to order.

I am delighted to welcome all to this hearing on the reauthorization of the NSF. I am very pleased that the Commerce Committee is holding this hearing today to consider that reauthorization.

Obviously America's leadership in science and technology is at the center of a significant debate today, and it is also, I think, agreed upon by all parties in the debate that the question of our leadership in those fields is really at the center of our ability to maintain a strong, competitive posture in the world today. NSF obviously has played a very significant role and will continue to play a very significant role in the capacity to compete. Perhaps some are placing higher expectations on NSF than might be warranted. I do not know, and that certainly may be one of the subjects of today's hearing.

But I am convinced that there isn't a more important issue for this country to come to grips with quickly than the question of how we are going to compete and what kind of resources we are going to put behind that effort if, indeed, we are serious about it.

Recent trends simply underscore the need to try to respond with respect to this issue, and I think that four areas stand out above all others. The first obviously is the eroding base of our university research enterprise. I think that some of our brightest investigators are being forced to work with dated equipment, without the facilities that they need. Construction and renovation of academic research facilities have been estimated to cost somewhere between \$5 to \$20 billion, and could take anywhere from 10 to 20 years to complete. The cost between closing the gap between present university

instrumentation and that which is required to insure maximum productivity is estimated to be in the vicinity of \$1 billion alone.

So, in the face of those needs we have seen a reduction in our Federal obligations for academic research and development of about 90 percent between 1966 and 1983. Obviously a significant question can be raised here.

Secondly, a very disturbing trend in the whole direction of R&D and R&D expenditures. There has been a significant increase in the R&D expenditures from 1982 to 1986 but this has been principally an increase in DOD expenditures, primarily from the star wars initiative. And I think Director Bloch, who is with us today, has emphasized that we are now reduced to only one-quarter of all Federal dollars in research, research going into the civilian side. In fact, U.S. civilian R&D as a percentage of gross national product is now below that of Japan and West Germany, our principal industrial competitors. And as Dr. Bloch has pointed out previously, the DOD funds have been directed toward shorter term investments with only 3 percent going to basic research. So, we are short-changing ourselves in that area.

Thirdly, I think there has been a growing recognition of the importance of science and technology to economic health from the development of new products and the creation of new jobs and increased productivity. We have certainly dramatically demonstrated this in my State of Massachusetts where our blend of mature industry and high technology enabled us to weather the recession of the early 1980s and emerge into a significant period of economic growth.

And finally, the last trend that I think makes this hearing even more important is the fact that we are at the threshold of a whole new era of exciting developments in fields such as biotechnology, microelectronics, supercomputers and so on. And we need to take specific and immediate steps in order to maintain our leadership in those areas or, again, we stand in danger of falling behind the countries who are more willing to take seriously those opportunities and those challenges.

I think it is clear that our national security literally depends perhaps more on our ability to compete than it does on the next generation of weapon systems or of some other priorities that have been set. And I think that our ability to create that research base in these next days and fuel that technological innovation is really what is at stake here.

I am obviously encouraged, as I think my colleagues are, that this year's NSF budget shows an increase, and it is on that note that I would like to introduce our first witness today. Before I do, I will turn to my colleague here. But I have had the pleasure of working over the last year in the 99th Congress as a member of the Economic Competitiveness Task Force of the Democratic Caucus. And that was headed up by Senator Bingaman who will be our lead witness.

Before I introduce Senator Bingaman further, let me turn to my colleague, Senator Pressler, and ask if he has an opening statement.

OPENING STATEMENT BY SENATOR PRESSLER

Senator PRESSLER. Thank you very much, Mr. Chairman. I think it is very appropriate that we should be looking at the National Science Foundation and the Foundation's contribution to the U.S. industrial competitiveness. Let me welcome Dr. Bloch here and say that I have enjoyed working with you on the School of Mines continental drilling programs.

I do feel strongly that my State of South Dakota has not done well in terms of being a part of the National Science Foundation—some of the grants and some of the research. And we are trying to change that. Perhaps in part it is our own shortcoming in the sense that we don't have a lot of post-doctoral research or post-doctoral programs funded by our state legislature. You have to have somebody to apply for the funds in order to get them.

However, I do think there is also a problem with the peer review process, and I have tended to support the peer review concept, but I just do not believe it is working. As one of my colleagues has pointed out here, most of the peer review process goes to Ivy League schools or the big schools along the Mississippi. There is an old boys' network of Ivy League and people from those big universities. We do have the EPSCoR program now. My state has applied, but I guess there have been problems with the applications. And we are working hard to correct those, and I am working with people in the state.

But the point is in an ideal world, Congress probably shouldn't allocate these grants on an appropriations basis, on an ad hoc basis. And in a perfect world, the peer review process sounds the best. I guess all the professions want to have peer review. The various groups want to have peer review. But in fact, sometimes peer review can be an old boys' network dividing up the pie among themselves. And that is to some extent what has happened with some in this Senator's judgment.

Well, let me say, first of all, in general in welcoming our witnesses that 30 years ago the Soviets launched Sputnik, and our lead in science and technology was challenged at that time. And I remember it well being a high school student then. And I am sure Senator Bingaman was in the same situation.

Today the challenge to our scientific and technological lead is less tangible but no less dangerous. This challenge is not marked by a single event. Instead people lose their jobs, farms fold, factories close, and our trade deficit grows because of foreign competition.

Our country responded to Sputnik with a massive investment in science and engineering. The number of scientists engaged in university research more than doubled, and the graduate student population tripled. And I recall well the National Defense Education Act and, in fact, attended the University of South Dakota in part on a loan from that program.

Our country can and must respond again today. We have more talented people and more resources than any other nation in the world. We can put our resources to work if we strongly support university and college research.

Last year I introduced the Strategic Defense Education Act of 1986. The act provided fellowships for U.S. students interested in pursuing science and engineering degrees and provided funds for the improvement of university facilities and equipment. While many of the act's provisions were enacted into law, a need still exists for many of its programs.

In recent years a number of American students receiving graduate degrees in science and engineering has dropped precipitously. In engineering nearly half the graduate students are foreign students. At the undergraduate level the percentage of Americans majoring in science and engineering has also declined since the 1970s. If our country is to compete, we need a pool of scientifically educated people. Providing more fellowships will help more students become involved in science.

We also need to broaden the base of science without sacrificing the excellence of existing research. A broad base will involve more people in science and realistically reflect the distribution of scientific achievement in the United States. The so-called second-tier schools educate over half the science and engineering baccalaureates. Forty percent of the students later receive graduate degrees. Expanding this base will benefit the university community and the country. Federal funds should not be concentrated in only a few institutions with the benefits accruing to only a few states. Instead Federal funds should be widely distributed to encourage competition and to ensure that all areas of the country realize the benefits of science and education.

If our country is to compete, we need to draw upon the talent that exists in second-tier schools. We need to involve the smaller institutions that exist in South Dakota, South Carolina, Missouri, Michigan and Massachusetts. We will need to involve the entire college and university system, not a select few.

So, Mr. Chairman, I want to say as a clear part of my opening statement that this Senator is moving away from the peer review process or confidence in it because of the way the funds have been distributed. Ideally we would all like to see the peer review process, but I shall resort to the appropriations process at some point. I do believe the EPSCoR program will help my state. As I said, part of it is the responsibility of the state legislature and the state. There has to be somebody to apply. There has to be a post-doctoral program. There has to be a doctoral program. There has to be research going on first for somebody to apply. And we are working on that.

But with that, Mr. President, I would like to thank you for chairing this hearing, this important hearing. I think it is one of the most important subjects that we are discussing in Washington today.

Senator KERRY. Thank you very much, Senator, and I thank you for the promotion from Chairman to President.

Senator PRESSLER. You're very welcome.

Senator KERRY. Senator Bingaman I think must have mixed feelings today because a couple of years ago he was one of the lonely voices out there in the wilderness talking about competitiveness when it was not a buzzword, and now it is a buzzword. And I think he shares a mutual concern that the issue does not go the way of a lot of buzzwords up here. That it will get a band aid response, and

then people will walk away believing that we have somehow done something. But I think that all of us owe Senator Bingaman both acknowledgement and gratitude for the early perception he showed about what was happening and his dedication to this issue.

Last year he chaired a group that met once a week every week through the year and put together what I consider to be, notwithstanding the fact I was a member of it, a series of significant the realistic proposals, many of which, I should add, have been subsumed into the administration's current budget and proposals on competitiveness. So, I am delighted to welcome someone who knows what he is talking about on this subject. Senator Bingaman.

STATEMENT OF HON. JEFF BINGAMAN, U.S. SENATOR FROM NEW MEXICO

Senator BINGAMAN. Well, thank you very much, Mr. Chairman or President, whichever you prefer.

Senator KERRY. You mean it is that easy? I can choose?

Senator BINGAMAN. That's right.

When you have the gavel, you can choose whichever.

It is a pleasure to be here, and it was a pleasure to work with you this last year on the Senate Democratic Working Group on Economic Competitiveness. I do think we came forward with some useful suggestions, many of which have been adopted.

I think you and Senator Pressler have made some important points about the importance of education, and particularly science and engineering education, to the future economic prosperity of the country.

The bottom line of all this talk about competitiveness is what is happening or in danger of happening to our standard of living in the country. That is the way the issue comes home to the average American. Between July of 1981 and July of 1985, we created 9.5 million jobs in the service sector in this country. But at the same time we lost 1.2 million in manufacturing, and we lost another 400,000 in the mining industry. The average wage for those jobs created was \$272 per week. The average wage for those jobs lost was \$444 per week. This translates into a significant decline in the standard of living for American workers.

I think that it is clear that a good share of the cause of this decline is the fact that we are now in a global economy. We are facing competition in manufacturing and in other basic industries that's really unprecedented.

The response to this competition has to include a dramatic improvement of our educational system with particular emphasis on science and engineering education. I believe Mr. Chairman, along with your own comments, that our educational and scientific system in this country has suffered from neglect and indifference in recent years. Investment by the Federal Government in human capital has dropped in recent years. And the estimates of the Office of Management and Budget are that it will continue to be very low in future years.

Today, I would like to specifically address three problems that need immediate attention and that we have recommendations for dealing with. First, is the decline in science and engineering educa-

tion, particularly at the graduate school level; second, the deterioration in our scientific infrastructure which you referred to in your opening comments; and third, the difficulty we have had in moving our basic science research into commercial products.

Let me go back and first deal with what I see as a decline in science and engineering education particularly at the graduate school level. It is clear that too few of our students today who are in science and engineering are continuing on to their doctorate degrees. We have had a stagnation in the number of science and engineering bachelor degrees between 1974 and 1982. In contrast, there were large increases in the numbers of students in science and engineering receiving bachelor degrees in the 1960s and in the 1970s. More importantly, there has been a decline in the number of science and engineering doctoral degrees in the same period down from the peak in 1974. The number of students has increased recently in the last few years, but it has not increased enough.

Without students working for doctorates in these programs today, we will clearly not have the professors tomorrow to carry out the needed basic research and to train the future scientists and engineers of this country. In the fall of 1983, 9 percent of the full-time faculty positions in engineering in this country were unfilled. Between 1976 and 1983, faculty employment grew 32 percent while student enrollment grew 57 percent.

Part of the problem here, Mr. Chairman, is money. Most graduate students in science and engineering require some type of financial assistance, but there are a limited number of fellowships available.

Another factor is that there is a significant lack of foreign study by U.S. students in science and technology. Over 55 percent of all doctoral engineering degrees awarded in the U.S. since 1983 have been to foreign students, and almost half of those have returned to their home countries once they receive their degrees. Since 1980 only 12 percent of U.S. engineering students receiving degrees actually studied abroad.

The second problem I wanted to address very briefly is the problem of deteriorating university research facilities. The 1982 National Science Foundation survey of department chairpersons determined that half of those surveyed responded that their research instrumentation was inadequate to enable investigators to pursue major research interests. Only one-fifth of the laboratory instrumentation in our universities was considered state of the art. A perfect example of the problem is in the field of material sciences. Today we are in the middle of a major revolution in material sciences with superconducting materials being only the latest example. Yet, in 1982 the National Science Foundation survey revealed that the median age of instrumentation at that time was 11 years, which I think is clearly too long.

Lack of Federal funds is a major factor. In 1983 the Federal Government provided only 12 percent of the total academic capital expenditures for facilities and equipment. That was down from 19 percent in 1980. While there have been some increases in funding from the private sector, the lower percentage reflects an absolute decline in capital expenditures between 1976 and 1982. Capital expenditures have been rising since reaching bottom in 1979, but not

nearly fast enough to repair the damage. Estimates are that it could take anywhere from \$5 billion to \$10 billion to renew and replace the scientific and technological infrastructure in our universities.

We have had an inability as well, Mr. Chairman, to move from basic research to actual products for sale in the marketplace. One example that I have already referred to, which is of great concern I know to Mr. Bloch and many others in our government, is the whole area of superconductivity. Much of the research there was supported by the National Science Foundation's individual grant's program. But recent actions, particularly by the Japanese in putting together a consortium to commercialize and to find commercial applications for some of these new breakthroughs, are a cause for concern.

When we get to solutions, there are many that have been proposed in the Congress. Let me just indicate three solutions that are contained in the product of our working group this last year, which has now been introduced in this Congress as S. 374. Titles III, IV and V of that bill I think try to deal with these particular problems in concrete ways.

The first is a proposal to add additional National Science Foundation fellowships. I am heartened, as I know you are, by the fact that the administration has called for 200 additional graduate National Science Foundation fellowships. In my view and in the view of our working group that is too few. Our recommendation this last year was that 500 new fellowships be created for five years, and that these be for the study of sciences with a particular emphasis on students who had an interest in foreign languages and foreign study.

We also recommended as a solution to the problem of outdated university facilities the creation of a University Facilities Fund within the National Science Foundation. The recommendation is that \$250 million per year be allocated for 10 years beginning in 1988 for this facilities fund, which would be administered by the Director of the National Science Foundation. The funds would be allocated on the basis of peer review, and all funds would have to be matched on a 50/50 basis by non-Federal sources.

The third recommendation was a doubling of the engineering research centers. I am glad to say that the administration has, in essence, adopted this recommendation in their budget submitted this year. The Administration has also asked for funding for science and technology centers, which I personally would support. I think it is clear that we would not want the funds for either the engineering research centers or the science and technology centers to come from the National Science Foundation's individual grant's program.

Mr. Chairman, maintaining a world-class scientific system is crucial to our economic future. It is clear that we cannot maintain a world-class scientific system without adequate levels of funding and without first-rate scientists and first-rate university facilities. The more we let our best young minds drift away from science and engineering, as I believe we have to too great an extent, the closer we come to becoming a second-rate scientific nation and thereby falling behind our competitors.

I hope this committee will seriously consider the recommendations that we made last year in the working group and in particular those three I have referred to today. I thank you very much for the opportunity to be here, and look forward to continuing to work with this subcommittee.

I also would indicate before I quite my testimony that Senator Rockefeller was also part of our esteemed group working on these proposals and I think made a very valuable contribution. I hope you both can prevail in successfully reauthorizing the National Science Foundation with this added authority that we have discussed here today.

Senator KERRY. Senator, thank you very much. I appreciate your testimony and, again, appreciate your leadership on this.

We are getting a little sandwiched for time here. We have a vote on. What I would like to do is ask Senator Rockefeller before he makes an opening statement if he has any questions he wants to ask Senator Bingaman. If not, I will ask maybe one. Otherwise we can recess, and then we will start with your opening statement when we get back.

Senator ROCKEFELLER. Why don't you just go ahead.

Senator, let me just ask you. There is a lot of heat around over the issue of the peer review process, et cetera, and I do not want to get mired in that in principle at this point although I know you have been a strong supporter of the peer review concept.

But is it not fair to say that if we were to have a facilities fund and begin to pay attention to this question of developing resources and maintaining the current resources, that that would most likely diminish this whole pressure on the earmarking debate? I mean, absent that kind of fund and that kind of direction, it becomes far more heated and far more intense, does it not?

Senator BINGAMAN. Well, I think that setting up this fund would help because it would indicate a commitment to deal with the problem on a more systematic basis than we have been able to in the past. I have been a strong supporter of the peer review system, and I think that overall it is an infinitely better system for allocating research and facilities funds than any that could emerge from our deliberations here in the Congress. If there are problems with the peer review system, the solution is to refine the system and eliminate the problems. The solution is not to sidestep the system and go to some kind of direct congressional determination of where research and facilities funds should go. I think we have too few resources to spend on our important research and improvement of these facilities for us to be allocating it on the basis of political influence. So, I think it is crucial that we have a systematic approach to it. I do think that this university research facilities fund would help us to have that kind of systematic approach.

Senator KERRY. You have always been pretty willing to give credit where credit is due, and I hope I am not reaching in saying that for the last few years this administration has shown a willingness to ignore some 30 or so blue ribbon panels, including the Young Commission which was put together to advise on this subject. So, I take it you are somewhat heartened that after your task force put out its recommendations, the administration began work on a competitive initiative which showed that they did listen to

your group. And I would take it you are willing to give them credit for listening to you.

Senator BINGAMAN. Well, I am not sure they listened to us. As you say, there have been a lot of groups and a lot of studies calling for initiatives in these areas. I am, of course, glad that the administration has embraced some of the initiatives of the working group. I think there are still others, such as the problem with university facilities, where the administration has not given attention to and where I think the Congress still needs to take leadership.

But I am heartened. I am heartened by the increased funding that they have requested for the National Science Foundation and their stated commitment to double the budget of the National Science Foundation in the next five years. I think that is a major step forward. I wish that had come earlier in the administration. I think the need has been there for some time, and I think we have seen a neglect of our non-defense research activities in the 1980s which I think we are now, hopefully, getting around to curing.

Senator KERRY. Thank you very much, Senator.

[The statement follows:]

Testimony of Senator Jeff Bingaman

On activities of the National Science Foundation
and its role
in U.S. industrial competitiveness

presented before
the Science, Technology, and Space Subcommittee
of the
Committee on Commerce, Science and Transportation

May 28, 1987

Mr. Chairman, I am pleased to be here to testify on the importance of science and technology in our continuing ability to compete economically in the world, and specifically on the role of the National Science Foundation. I want to congratulate the Chairman for scheduling this hearing and his leadership on this issue. I am pleased to note that you served with me last year as a key member of the Senate Democratic Policy Committee's Working Group on Economic Competitiveness.

Much has been said about America's trade and competitiveness problem. Even as the Senate is in the middle of work on comprehensive trade and competitiveness legislation, there is confusion over the nature of our problems. What is clear is that America faces a crisis in our ability to compete in the new global economy. Our \$170 billion trade deficit is part of the problem.

The bottom line, however, is the decline in America's standard of living. Between July 1981 and July 1985, the U.S. economy created 8.6 million new jobs. However, during that time, 9.5 million jobs were created in the service sector while 1.2 million jobs were lost in manufacturing and 400,000 jobs lost in mining. The average weekly wage for the jobs created was \$272 while the average weekly wage for those lost was \$444. This translates into a real decline in the standard of living for many of our citizens. The average weekly earnings of all American workers has decline over the past 12 years and is now below its 1963 level.

What has happened? Simply put, the world has changed. America is now part of a fast-moving global economy. The easy economic superiority which we enjoyed in the 1950's and

1960's is now gone. In those days, our economic strengths -- raw materials, finance, invention, and efficiency -- allowed us to take our competitive advantage in the world economy for granted.

Now, advanced technology and the changing terms of international trade are remolding the basic structure of international economic competition. Both capital and technology move across international borders with unprecedented ease and speed, seeking the lowest cost location available for production. This means moving to nations where products and services can be produced by people with minimal skills who are willing to work hard for relatively low wages. With the low cost of transportation, products made and services rendered in these low cost and low wage nations can be transported cheaply to the United States.

These developments challenge the most basic premise of the American economic system. This country built the world's most productive economy based in part on mass production techniques that made it possible to employ workers with modest skills to turn out high quality, inexpensive products in great volume. This is precisely the game at which we today are being beaten, because the most modern machinery is now available to others who are willing to work much longer hours than we are, at much lower wages.

If America wants to compete on the same terms as in the past -- making the most of workers with relatively low skill levels -- then it must accept the prevailing world wage rate for low-skilled and semi-skilled labor. That is, we must be prepared for a significant decline in our standard of living.

The alternative is to pursue a renewal of the American economy through harnessing the power of knowledge to work smarter. The link between our standard of living and our educational and scientific system is clear. Since we cannot cut ourselves off from the rest of the world economy and we should not seek a competitive advantage by drastically lowering of our standard of living, we must rely on our superiority in science and technology. America's future economic development must be based on its educational system and the quality of the science which the educational system has produced.

This excellence does not come easily. It is something that must be nurtured and cultivated. I am concerned that our educational and scientific system has been not nurtured, but seriously harmed by this Administration's neglect and indifference. Investment in human capital has dropped sharply during this Administration, and OMB estimates for future years are even lower.

This neglect has created a number of problems within our educational and scientific system. Today, I would like to focus on three specific problems: the decline in science and engineering education, especially at the graduate school level; the deterioration of our scientific infrastructure; and our inability to move from basic science to commercial product.

Nationwide, too few of our students enter science and engineering and too few of these continue on for their Doctoral degrees. The number of Bachelor's degrees awarded in science and engineering in the United States between 1974 and 1982 has remained stagnant after a large increase in the 1960's and early 1970's. At the same time, the number of Doctoral degrees in science and engineering declined from its peak in 1974. While the number of graduate and undergraduate students in science and engineering has increased recently, there are still too few students pursuing graduate studies.

Without students in doctoral programs today, we won't have the professors tomorrow to carry out the needed basic research and to train our future scientists and engineers. Even today, we have a problem in finding enough professors in science and engineering. In the fall of 1983, a survey of engineering deans showed that 9 percent of all full time engineering faculty positions were unfilled. Between 1976 and 1983, the number of engineering professors grew by 32 percent compared to a 57 percent growth in student enrollments. This means more students per professor, larger classes, and a lower quality of education.

One of the major barriers students face in continuing their education is money. Without adequate student financial aid, our best young minds cannot pursue their education or go on to graduate education. Student aid is especially important for graduate studies. Most graduate students in science and engineering receive some form of financial assistance. But, the availability of financial assistance is limited.

Another facet of the problems is the lack of interest on the part of U.S. students in scientific and technological developments in other nations. The United States has long been educator to the world in science and engineering. Over 55 percent of all doctoral engineering degrees awarded in the U.S. since 1983 have been to foreign students, almost half of which returned to their home countries. However, development of science and technology is increasing world-wide. For example, some of the recent advances in superconductivity have been made at the University of Beijing, China. Yet, since 1980, only 12 percent of U.S. engineering degree recipients study abroad.

The second problem is the deteriorating condition of university research facilities. In a 1982 NSF survey of department chairpersons, almost half responded that research instrumentation in their departments was inadequate for pursuing major research interests. Only one-fifth of the laboratory instrumentation may be state-of-the-art. A perfect example is in the field of materials science. Today we are in the middle of a major revolution in materials sciences -- superconductive materials being only the latest example. Yet, the 1982 NSF survey revealed that the median age of instrumentation was 11 years and that 81 percent of instrumentation had to be shared among users.

While NSF has tried in recent years to attack the problem, its resources devoted to instrumentation and facilities are inadequate. By 1983, the Federal government accounted for only 12 percent of total academic capital expenditures for facilities and equipment, down from 19 percent in 1980. While there has been some increase in private funding, this lower percentage reflects an absolute decline in capital spending between 1976 and 1982. Capital spending has been rising since hitting bottom in 1979, but not nearly fast enough to repair the damage. Estimates are that it will take between \$5 and \$10 billion to renew and replace our scientific and technological infrastructure.

America not only needs to restore its educational and scientific base, it needs to regain its ability to commercialize technology. We still lead the world in Nobel-prize quality research, but we face difficulty in moving from basic research to commercial products. The recent breakthrough in superconductivity is a good example. Much of the research, including the work done at the University of Houston, was supported by the Federal government through NSF's individual grant's program. Yet, shortly after the breakthrough was announced, the Japanese government had put together a consortium to find commercial applications for this new technology.

There are solutions to these problems. Last year, the Democratic Policy Committee's Working Group on Economic Competitiveness, which I chaired and you, Mr. Chairman, were a valuable member of, proposed a multipronged program to attack these problems. I would like to recommend particularly three of these proposals, which are contained in S. 374: additional NSF graduate fellowships, a facilities fund, and additional Engineering Research Centers. Some of these proposals have been adopted in part by the Administration. However, the Administration's proposals do not go far enough.

The first proposal goes to the heart of the lack of money for graduate studies. I am heartened by the Administration's call for 200 additional graduate NSF

fellowships. However, more needs to be done. The Working Group called for the creation of a new "Scientific Research Fellows Program." The program would award 500 new fellowships each year for five years. These fellowships would go to outstanding graduate students to pursue studies with the promise of contributing significantly to America's efficiency, economic productivity, and international competitiveness. Because of the growing importance of foreign sources of science and technology, special consideration should be given to applicants who demonstrate competence in the language of a foreign country identified as important to America's international competitiveness and who intend to perform a minimum of two years research in that country. The Fellowship Program should also make available additional funds for foreign travel and for foreign language instruction.

The second proposal is for the establishment of a separate University Facilities Fund within the National Science Foundation, with a budget of \$250 million for 10 years, to help maintain our scientific infrastructure. To ensure excellence, all proposals would be submitted to peer review within the scientific and technological community and all awards would be made on a 50/50 matching basis with non-federal funding. Such a separate fund would permit NSF to begin the task of rebuilding our scientific infrastructure without diverting needed resources away from research activities.

Finally, the Working Group called for a doubling of the NSF Engineering Research Centers, which concentrate on applied research and development of generic technologies. I was happy to see that the Administration's NSF budget request has taken this suggestion to heart. This is certainly a refreshing change coming from an Administration in which the idea of government support for technological development has been viewed as an anathema. I also support increased funding for the Science and Technology Centers, which would undertake multidisciplinary research in basic science and technology.

However, such funding should not be at the expense of funding of individual grants for basic research. As important as these centers are, individual research grants are at the heart of our scientific accomplishments. We should not cut one to advance the other. Both are necessary.

Mr. Chairman, maintaining a first rate scientific system is crucial to our economic future. We cannot maintain a first-rate scientific system without adequate levels of funding and without first-rate scientists and first-rate university facilities. The more we let our best young minds drift away from science and engineering, the closer we steer toward second rate scientific status, and thereby fall behind competitively. I hope the Committee will study the recommendations of the Senate Democratic Policy Committee's Working Group on Economic Competitiveness, which I have outlined today, and will act favorably on these recommendations. Thank you for the opportunity to be here today. I would be happy to answer any questions.

Senator KERRY. Senator Rockefeller, do you have a statement you want to make at this time?

OPENING STATEMENT BY SENATOR ROCKEFELLER

Senator ROCKEFELLER. Well, first of all, Mr. Chairman, I want to thank Senator Bingaman because there has been a lot of high profile work that goes on in this body over the few years that I have been here. But the area of competitiveness has not until recently become one of them. But Senator Bingaman is one of the two or three senators in this body who from the very beginning has consistently, persistently showed interest.

And the word is not in favor, but the problem is the most desperate one. In fact, it is the largest part of the trade deficit that we face, and Senator Bingaman has been right on top of it from the very beginning in his persistent, constant probing way. And that has inspired me because Senator Bingaman asked me to work with the competitiveness task force. It meant a lot to me, and your constant leadership is something that I think ought to be recognized and I certainly want to do, Senator Bingaman.

And I agree with you, Mr. Chairman, just before we go to vote here. I too am pleased with this increase in funding for the National Science Foundation. I think it is very important that basic research and development is going on there.

I must say I wish that the same approach had been taken for the National Bureau of Standards, that there had been a greater increase for the National Bureau of Standards. Between these two organizations you have a marvelous merger with research and development at NSF, and with National Bureau of Standards, you have the turning that research and development innovation into things that work on the factory floor; the commercialization of innovation, which is what this country has to do.

But I am very happy. I think the doubling of NSF's budget over the next 5 years, if that is something that this committee in an authorizing function and the rest of the Congress will keep up with, that is what has to happen.

I have talked with Mr. Bloch for whom I have the highest regard—and I try to say that publicly as often as I can, and privately as constantly as I can also—that there is a need to get research and development funds to various universities, not only those which clearly and obviously deserve them and clearly and obviously get them. Not every place is an MIT or not every place is a Cal Tech. I wish every place were. That isn't the case. But science and technology research and development is the preeminent challenge for this Nation now. Universities do that.

I have to point out, Mr. Chairman, that according to a GAO study, West Virginia University was listed last in terms of research and development funds from the Federal Government. But I have talked with Mr. Bloch about that. Mr. Bloch is sensitive to that, and he is coming to West Virginia University on July 10, which I am very proud of, and I think that shows his own commitment towards the National Science Foundation in general and towards equity in particular. So, I am grateful, and I am a strong supporter of his and the National Science Foundation, as he well knows.

Thank you, Mr. Chairman.

Senator KERRY. Thank you very much, Senator Rockefeller. I appreciate the role that you played also in that task force effort.

I am going to recess for as short a time as possible so we can go and vote. I do not want the hearing to continue without us all here. So, if you would bear with us, we will return as fast as possible, and we stand recessed until such time.

[Recess.]

Senator KERRY. We have got a lot of ground to try to cover, so I am going to try to get moving because we have got another panel to follow this one with important testimony with a number of witnesses.

So, Mr. Bloch, if it is possible—I don't want to cramp you at all here—if you could summarize, if you feel comfortable doing that, it would obviously help move things along. And needless to say, we will put your full testimony into the record. Without further ado, I look forward to your testimony. Thank you.

STATEMENT OF HON. ERICH BLOCH, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Mr. BLOCH. Thank you, Mr. Chairman. I will try to be short and summarize, but I need to make a few points I think and highlight a few activities of the National Science Foundation.

Senator KERRY. Let me just say I don't want you to feel cramped at all. I want you to make sure you cover what you think is important and go right ahead and do that.

Mr. BLOCH. Thank you. I appreciate the opportunity to appear before this committee, and I want to thank the committee and the Chairman for the continued support that this committee has shown for NSF and for its mission.

I think we have heard a great deal in recent months about our country's need for economic competitiveness, and the debate is a very welcome one. It is time that economic competitiveness moves to center stage. For too long we have searched for sources of our economic problems outside our own boundaries, such as unfair trade practices, low wages in other countries or unfavorable exchange rates.

But recently we have realized that to compete successfully as a nation, the most important thing is to stay ahead of our competitors and do a better job than they do.

We can succeed, if we look to our own resources, of which I believe the most important are new knowledge and well-educated people. These are the key elements of a competitive economy. New knowledge, which we get through basic research, is important because it is the basis for the new products that we need to compete in world markets, and for the new processes we need to improve our manufacturing and our service industries. Education is important because talented and well-trained people are the source of the new knowledge and are the main resource needed to put that new knowledge to work.

New knowledge and education are prerequisites of economic strengths and competitiveness in the modern world. Both knowledge and people are produced in universities. That is why it is so

important to increase investment in our universities, and that is the central idea behind the Fiscal Year 1988 budget request for NSF.

Our request for 1988 is almost \$1.9 billion. That is nearly 17 percent above the appropriation for the current year. It reflects the importance the administration has attached to basic research and education in science and engineering, particularly in our colleges and universities.

In addition, the administration is committed to increases that will double our budget by 1992. This commitment is unusual, but very important. It establishes a strong base from which we can plan our future. This multi-year authorization will also allow us to develop a more coherent strategy for the Foundation's programs. The proposed increase will significantly raise support for university basic research and that will help preserve our lead in science, engineering and technology.

The increase is needed because our trading partners have moved ahead of us in important industrial technologies as their investments in R&D and education have increased. Mr. Chairman, you have focused on that problem before.

In fact, the United States is now only fourth among the industrialized countries in the fraction of gross national product invested in civilian research and development. Too few of our students are choosing science and engineering careers and too few of those who do continue to the Ph.D.

Japan produces more engineers than we do with half the population. And, Japan also spends a higher percent of that country's R&D on basic research than we do—12.6 percent versus 12.0 percent. We hear many times that Japan does not spend anything on basic research, and that is a myth.

The fraction of Federal R&D support that goes to universities has been dropping, and so has the share going to basic research. That is not the way to stay competitive. The government's role in support of basic research and education is critical. This is a long-term matter. Nothing we do here will produce quick results but in the long term nothing else we can do will have surer results.

Concern with the long-term means concern with all parts of the science and engineering base. The Foundation is the only Federal agency with such broad responsibility for basic research and education. NSF encourages research on the boundaries between the disciplines. NSF supports science and engineering education in ways that link education and research in a symbiotic manner. And NSF encourages cooperation between universities and industry and among Federal, state and local governments. NSF also supports developing institutions and regions and undergraduate institutions.

One of the major themes in our 1988 budget request includes enhanced support for education and human resources and the broadening of participation in the research enterprise. People are our most important resource. Reflecting this, our budget proposes a 50 percent increase for education and human resources. This represents a fresh commitment to the Foundation's traditional support of graduate fellowships, undergraduate education, precollege education, and support for underrepresented groups—women, minorities, and underrepresented states.

I am sorry that Senator Pressler is not here, but I would really urge him not to throw the baby out with the bath water in his comment on the peer review system. The peer review system, no doubt, needs improvement. And we are looking at that. But the peer review system, besides allocating resources, has another function, namely, to guarantee the quality of our research, and therein lies the importance of the peer review system. It is very difficult to judge a piece of research which has a practical application 20 years hence. And therefore, the peer review system is geared to guaranteeing and underwriting the quality of the research, and we need to keep that in place.

Another strategic theme for 1988 is support for science and technology centers and groups which will receive an increase of \$80 million. There will be additional engineering research centers and centers for biotechnology, material science and computer and information sciences. These centers are located at universities. They are multidisciplinary, and they are organized for strong industry involvement. They do basic research on problems that are important to science and important to competitiveness. This is the program that the President announced in his State of the Union address and featured in the draft Trade, Employment, and Productivity Act submitted to Congress.

A major purpose of the centers is to help speed the transition from basic research to new commercial technologies, a subject that was discussed before. In the past this has taken much longer than we would like, as much as half a century. There is no easy way to change this. But part of the answer is to get the universities, where most of the basic research is done, in closer touch with industries that may use it. Researchers need to know how industry looks at problems and what industry sees as possible ways to advance. Industry needs to know what university basic researchers are doing, what they consider important, and what they consider possible. Both sides need to pool money, talent and equipment to work on interesting problems. People need to flow both ways in a steady stream because knowledge is most easily transferred when the person who has it moves from one side to the other.

The third theme of this budget is steady investment in basic disciplinary research and facilities. This is NSF's most important activity and will increase substantially in Fiscal Year 1988. It is important to understand that, by its nature, the research process cannot be planned. Not all projects deliver on their promises, and often the most significant insights come in unexpected ways, nor can the technological or economic payoff be foreseen in many cases.

But history tells us that the payoffs are there and are often dramatic. Just as an example, the high temperature superconductivity breakthrough of the last few months that is much in the news today is a phenomenon with a long history. Superconductivity was originally discovered in 1911, and for a long time the practical applications were very limited because maintaining very low temperatures was expensive.

Within recent months researchers in industrial laboratories and at universities here in the U.S., in China and in Europe (which also, by the way, shows the international nature of science) have

demonstrated that superconductivity can exist at much higher temperatures which can be achieved through inexpensive liquid nitrogen.

Much of the activity in this country has been funded over the years by NSF. We are increasing it substantially to take advantage of the opportunities in this important field. As a result, the cost of superconducting may drop a hundredfold and may revolutionize electric power generation and distribution, transportation systems and computing.

Finally, let me mention briefly the United States Antarctic Research Program, because I know it is of interest to this committee. We budget separately for this activity because of its heavy logistic needs and because the program serves geopolitical as well as scientific goals. Nevertheless, the scientific value of research is immense. Antarctica provides a unique environment for studies like ozone depletion, world weather systems, upper atmospheric physics, and aspects of the geosciences.

One issue with respect to the Antarctic that this committee has been especially concerned with is the need for a new ice-breaking research ship to replace the Coast Guard's old icebreaker GLACIER. The new ship will allow us to maintain a broad program of research in ocean and atmospheric sciences in the Antarctic region, and we have provided for the leasing of such a ship in our request for 1988.

Mr. Chairman, the President recently announced a major initiative that sets the United States on a quest for excellence. He said that our policies must serve three objectives. They must generate new knowledge in science and technology. They must swiftly transfer that knowledge to the marketplace, which Senator Bingaman has also focused on. And they must expand our Nation's talent base in science and engineering, and you, Mr. Chairman, have focused on that.

These are objectives that will be met in part through the programs of the National Science Foundation, but they are long-term challenges that will be met only by a long-term commitment to strengthen our science and engineering base. The Foundation's 1988 budget request and the commitment to double the budget over five years are a concrete start on this commitment. I urge the Congress and this committee to join together with the administration to make this commitment real. Thank you very much.

Senator KERRY. Thank you very much, Mr. Bloch. That is important testimony about an important subject.

I will put myself under a 10 minute first round here, and we will try and see where we go in that period of time.

You have justified the increases, as have others, in this current budget under the heading of competitiveness. Why are we doing it? We are doing it because we need to increase competitiveness.

On the other hand, NSF supports a broad range of sciences, many of which have no direct relationship to "industrial competitiveness." And I am thinking specifically of anthropology, astronomy, et cetera. They are worthy subjects, and nobody means to diminish that point, but if we are increasing the budget because of competitiveness, how much of the current funds in the 1988 budget

increases are going to go to fields directly related to economic competitiveness?

Mr. BLOCH. Well, that is a very good question, and it is a question that comes up time and time again.

First of all, we are talking about knowledge generation, and we are talking about education. The two are intermixed in our system, and that is the strength of our system. So, you cannot separate education from knowledge generation or basic research.

Secondly, you mentioned astronomy. That is an interesting example. Many people who were educated as astronomers in research universities found their way into industry. In fact, I just had a conversation with a couple of those astronomers who are today—have been for the last 10, 15, 20 years—at Bell Laboratories. They have made tremendous contributions because of their knowledge base in the communication theory area which led, obviously, to products that Bell Laboratories generated and which AT&T is selling in the marketplace.

So, one shouldn't very narrowly just look at a discipline and say, well, that is so far removed that nothing will happen. Many of the outputs from these disciplines—the education part, as well as the knowledge base—often in a very irrational way find their ways into actual products. Some of the work that was done on modeling in astronomy in the past, and on calculational approaches have found their way into tomography equipment. So, it is very difficult just to say that a given field has nothing to do with economic competitiveness, because how people move, how they apply their ideas is a subject that is very difficult and very complex.

So, I would say that whenever we generate knowledge and whenever we educate people, we are adding something to our posture in the economic competitiveness area.

Senator KERRY. Let me follow that up then with a sort of related question, if you will. And I appreciate what you are saying about this broad concept of knowledge. I think the questions here—and I am certainly not arguing with you, but I am trying to draw it out for the record. I think many people are asking the kinds of questions where you have limited resources, and while one wouldn't disagree with you that a great deal of knowledge will come and that knowledge base is critical, we are talking about limited resources with a very specific erosion of a specific base.

In line with that, the Foundation proposed to establish an ERC at Duke University in cardiology, and some are asking when it was that the United States lost its competitive lead in cardiology.

Mr. BLOCH. Well, we probably have a lead in that. That does not mean that we will always have a lead in it, but that particular center has been under scrutiny, as you know, by the National Science Board, not because the Board felt that it was inappropriate for NSF to fund it, but the Board felt that there should be some contribution from the National Institutes of Health, which has an interest also in that particular area.

The idea for that center, like all the centers that fly under the flag of Engineering Research Centers, come from the community itself along with the necessary industry participation. So, there is a need for it.

Let me say one more general point. If you look at our distribution of funds, they are not uniform. There are certain areas that receive larger increases than other areas, and that is how one sets priorities. And obviously in that priority setting, we are taking into account those areas that need more than others because they are behind or they are very important or they add directly to economic competitiveness. So, you should really——

Senator KERRY. How does the cardiology thing fit into any of those categories, the three you just listed?

Mr. BLOCH. As I said before, it is a very important subject, number one. And number two, the industry around it is an important industry for us.

Senator KERRY. What about the issue of NSF funding biomedical research while simultaneously NIH is very well-funded with respect to that?

Mr. BLOCH. Well, that is a problem obviously, and we are justifying funding that particular center not because of the basic science work, but because of the engineering work that is going on in this biomedical area. We are focusing very heavily in that center on engineering.

Senator KERRY. Let me make it clear, Mr. Bloch, that I am not trying to suggest that they shouldn't be funded according to a normal pattern of how NSF has chosen to do it. But as we get into this process of doubling the budget over five years, I think that there is going to be a much judgment and scrutiny about how that increase is going to be spread around.

My initial round is up. Senator Pressler?

Senator PRESSLER. Thank you, Mr. Chairman. I am sorry that I didn't get back, but I have notes from staff here with your fine comments on peer review. I think it is a good area for discussion and for wrestling with this.

You mentioned that you thought the peer review process was the best way to do it, but you suggested that there were needed improvements. What improvements would you suggest, and just sort of walk us through the peer review process as it now applies to NSF grants.

Mr. BLOCH. Well, we just had, over the last year, a committee in place under Dr. Hackerman, who is a previous president of Rice University and also former chairman of the National Science Board, to review the whole peer review process. And what I wanted to say before was that any process that you put in place needs review from time to time, and needs changes from time to time, and can be improved. We have had a lot of recommendations out of that committee, which we are just now implementing.

But let me make a couple of points about the process itself. First of all, it is not true that the peer review process looks at the merit of the research in isolation. There are four criteria by which the peer review process operates. One is the merit of the proposal, the scientific merit of the proposal. The second one is the research performance competence of the team or of the individual proposing to undertake that particular research. And that essentially says if the prerequisites are met, they have the capabilities of doing that research. The third one is utility or the relevance of the research itself. How important is that piece of research to science and engi-

neering, whatever the case might be, and also what are the utility aspects of it? What do we get from it? And the last one is the effect of the research on the infrastructure, of the total infrastructure of science. That has to do with universities and colleges and bringing them up to a level that is acceptable and where they can do further work. So, it is not just a very narrow view, "Yes, this is good science," or "This is bad science." The other three criteria are equally important.

Secondly, we have made a significant effort in making sure that what you called "the old boy network" does not occur. Both in our advisory committees and in our peer review panels, in our individual reviews, we are trying to bring in people who are not part of the normal system that you mentioned before. They are not from MIT. They are not from Berkeley and so forth. They are coming from smaller colleges, smaller universities, second-tier universities. They are geographically distributed. They are from underrepresented groups that we are trying to draw into this system: women, minorities, disabled. So, we are making a significant effort to use people who are not just coming from one class or from one group or from the upper tier of the universities. And I think that through that method we are going to get a better peer review system, and are also hopefully demonstrating the fact that this is a fair system.

Senator PRESSLER. You may or may not agree that if you are a new kid on the block, so to speak, you are sort of at a disadvantage in the sense that I suppose you don't have the facilities, and where do you get started? I mean, once you have a research base, then you can apply for more, and you have got a very legitimate base. It is kind of like in the law business they always say—they told our class at the Harvard Law School that you can always get a job with a law firm because the Harvard law graduates kind of pass the blue chip business around if they need a referral in another state and so forth. And I am not saying that is an old boy network, but it is just a natural thing I suppose.

I am not picking on the Ivy League schools necessarily, but the fact of the matter is that most of this research and maybe appropriately in some cases goes to Ivy League schools or schools along the Mississippi, those who are in the game, so to speak. And I know that the EPSCoR program has been designed to bring new players in, and I know that you have made efforts to bring new players in. Sometimes that is not easy because you can't just go out and give a research grant to somebody who does not have any base to do it or a plan.

But I am going to propose later—I would like to get a meeting with you and perhaps get another meeting with my seven major university presidents to see what we can do better.

What suggestions do you have for states such as South Dakota to improve the quality of their science programs?

Mr. BLOCH. Well, you mentioned the EPSCoR program. As you know, we have worked with South Dakota in that particular program. It has not resulted in an award unfortunately.

After the last declination, we had people visit your schools, and also your governor, to see what could be done to bring South Dakota up to a more acceptable level. We have urged them to move ahead on their own and then a year from now come to us for a new

EPSCoR kind of an award. And from what I know, the governor has agreed to do that. In fact, from what I understand, he has allocated some unspent dollars from a different source to make that happen.

Let me just—and not to rub it in, but just to cite an example to show that it can happen. South Carolina in 1978 was around 45th place in terms of NSF dollar support, and today it is in 27th place. I credit that to the success of the EPSCoR program in that particular state. So, the point is, it can be done.

Senator PRESSLER. So, the State has to make a diligent effort.

Mr. BLOCH. The state and the universities have to make a diligent effort, yes, together.

Senator PRESSLER. But you are confident that if they do, they will win some EPSCoR program grants.

Now, let me ask you to do this for me. And I know that you are not in the business of advising States. They have got to figure it out for themselves. Could you advise me as a Senator later in a memorandum or a meeting? Could you take a look at the South Dakota situation because we seem to be missing out in this area, and tell me what you think South Dakota could do better? It's something that I would like to learn as a Senator.

Mr. BLOCH. I would be glad to do that.

Senator PRESSLER. Let me ask you about a chart in your testimony, the last chart, chart 8 I think, or is it chart B? Chart 8, the National Science Foundation Support for Human Resources in Science and Engineering. First of all, there are the senior scientists. There 17,000. Then there are 3,000 post-doctorals. There are 16,000 graduate students, 7,800 undergraduate, 6,800 pre-college teachers, and 1,500 high school teachers.

In order to qualify for some of the really significant participation, I guess the State would have to have a lot of senior scientists and post-doctorals. Would that be a fair assessment?

Mr. BLOCH. In order to qualify for more of the funding of the Foundation, senior scientists are the most important group that you should have in place. They, in turn, will attract postdocs and they, in turn, will attract graduate students obviously. So, it has to start with the faculty. It has to start with the research and teaching faculty primarily.

And the other point I want to make is when one comes from that kind of a position, one has to focus on a few specific areas instead of trying to cover the waterfront. Science is a broad activity, and I am talking out of school obviously here because I don't know the situation. You know it a lot better. But I would suggest that South Dakota could do better if it would focus on its strengths instead of trying to cover everything. I would be glad to work with you on that and advise the universities. But the major effort has to come from the university itself.

Senator PRESSLER. Yes.

Mr. BLOCH. It has to know what its strengths and weaknesses are.

Senator PRESSLER. Yes. What is a senior scientist? We have the Eros Data Center there. We are trying to build a base in part from that, but also we have the School of Mines and Technology. But what is the definition of a senior scientist as used on this chart?

Mr. BLOCH. In general it is a professor at a university or the equivalent thereof.

Senator PRESSLER. And a post-doctoral is post-doctoral research. Is that right? Or post-doctoral program. Usually the States fund those, don't they?

Mr. BLOCH. No. No, we fund postdoctoral positions. Also, the State at times funds some of these positions either directly or indirectly, but so do we through our grant program.

Senator PRESSLER. I would like to ask some more questions, but I see my time is up on this round.

Senator KERRY. We will do another round here I think. Just picking up quickly from my colleague's question, conceptually is it in the best interests of the country to have replicated research ability all over the country? Does every State, does every university, have to have this ability? Will we be better off, or are we going to get into a point of saturation, duplication and waste?

Mr. BLOCH. Well, we can't expect every university to be an MIT or a Berkeley. That just does not work. There are not enough people around to make that happen. The support of these institutions is obviously very expensive. So, you cannot do it from a financial viewpoint, as well as from a human resources viewpoint.

I think what we need to do is to make sure that all the universities that are in existence reach a certain level of capability. And no doubt about it, there are certain universities that are not at that level now. That is what we are trying to accomplish with the EPSCoR program and other kinds of programs. But to expect every university to be an MIT, that I think will be an unfulfilled dream.

But can we do better? Yes, I think we can do better.

Senator KERRY. Well, hearing what you are saying—you know, I am not going to ask you directly because I understand the problems with OMB and elsewhere. But I am a very strong proponent and will be pushing for a facilities fund which was one of the recommendations we came up with in our competitive task force report.

Now, I understand that until the mid-1960s NSF had a significant role in supporting universities facilities. I wonder if you would describe the past support for research facilities during that period.

Mr. BLOCH. Yes. The first thing I wanted to say on the facilities issue, which is, by the way, a very timely one, is that one should not look at the past necessarily as a guide for the future. What was important, what was effective, at one time might not fit today's situation. So, I want to say that as a preliminary statement.

The picture today in the National Science Foundation is the following: We are spending about \$55 million on facilities. And while that might not sound like a large amount of money, it really supports only those special facilities that nobody else will be able to fund or can fund, like electron storage rings or telescopes.

With that \$55 million we are providing about 50 percent of the total Federal support for facilities. So, even though it's a small number, nevertheless the National Science Foundation is the biggest contributor to that very important area.

The second thing that I need to say is the following. About a year ago we conducted a survey of all of the universities that con-

tribute to science and engineering research. The report has been issued and you have seen a copy of it.

The report paints a mixed picture. First of all, as the report says, there is a problem. There is a facilities problem out there.

The report also says there is a lot of work going on in the facilities area. It is being funded by the States and also funded from private sources. It is not that there is nothing going on in terms of putting new facilities in place. There is quite a bit going on.

The third thing I need to say is that we have set our priorities—

Senator KERRY. Let me just interject there. When they say there is a lot going on, is there enough going on that the problem will not be a problem or is there still a problem measured against what is going on?

Mr. BLOCH. No. I acknowledged that there is a problem there. And whatever is going on, and quite a bit is going on from these two sources, these two sources alone are not sufficient to solve that particular problem. No doubt about it.

Senator KERRY. And is this a problem that literally restricts our ability to do what we need to be doing in terms of science and engineering?

Mr. BLOCH. Well, that is where you come into the priorities again. In the Foundation we have looked at that over and over. We have had many discussions among ourselves with the Board and with some of our advisory committees. We have come to the conclusion that with the restricted funds that are available today, we need to put our priorities in the following order: people first, support of people, be they research personnel or educational personnel. Second, instrumentation. Instrumentation, as Senator Bingaman pointed out, is in a very sorry state. And we think that is more important than the facilities. So, we put that in priority order. Twenty percent of our dollars in 1988 to instrumentation. If you had looked 10, 15 years ago, you would have seen maybe 5 percent going to instrumentation. That shows you the importance of instrumentation and also the need for it, and that we are trying to solve the problem.

And the third priority is facilities. Given that we have a fixed pie, I want to avoid taking money away from that fixed pie, putting it into facilities and, therefore, reducing the research base which we must maintain.

Senator KERRY. Assuming that we were not trying to take that money away from those other pieces of the pie, would a \$250 million sum of money sound exorbitant in terms of facilities expenditures in the country annually?

Mr. BLOCH. No, it does not sound exorbitant at all.

Senator KERRY. Does it sound reasonable?

Mr. BLOCH. It sounds reasonable.

Senator KERRY. Could it be more in fact?

Mr. BLOCH. Sure. It is a bottomless pit.

Can I answer the question you asked?

Senator KERRY. Yes.

Mr. BLOCH. What did we do? Well, we had a program which was called the NSF Graduate Science Facilities Program which was in

existence in the late 1960s and the 1970s. We spent about \$200 million in that program, about 977 awards.

In the beginning the program was for renovation. It wasn't for new bricks and mortar. It was really for renovation, and after a while it became a bricks program.

Simultaneously, in the same time frame, 1956 through early 1970s, NIH had a similar program for health research facilities. They spent about \$500 million on that program over that time-frame. That was a matching program, by the way, a program that matched almost one-for-one, or better than one-to-one, with other sources like the States and the private sector.

There was also a private program in place. The Ford Foundation granted large amounts of money between 1959 and 1966 totalling about \$350 million.

So, you see that in that timeframe there were at least three programs in place: one private, the other two from the government. And they all dried up about the same time, interestingly enough. There has been a hiatus from the mid-1960s to today of the Federal Government beginning a program.

I think we need to have a better understanding ourselves what the role of the various actors is. The Federal Government cannot support it by itself. I think we need to get the States involved, and we need to get private sources involved, also. Understanding the roles would be the first step toward addressing the facilities problem.

Senator KERRY. This is on a different subject. I appreciate your background on that. Recently you pulled out of a joint U.S./Soviet ocean drilling project. And I believe you pulled out because of pressure from the Defense Department. Can you explain the circumstances that led to that?

Mr. BLOCH. Well, yes. Not quite the way you described it. There is an Ocean Drilling Program in place. It has been in place for several years now and has international participation in it. Japan participates. France participates. England participates. A whole group of small European countries jointly participate in it. Canada participates in it. I probably forgot somebody.

A year ago we invited the Soviet Union to join that particular program. It was cleared at that time through channels. We offered the Soviet Union membership in this particular program but we did not receive a reply for almost a year. We sent the invitation in October 1985. We got an answer finally in November 1986.

We went through a second review because of the time delay between the first invitation and the reaction. We went through a second review, and the review came out negative for security reasons. The decision was made by the National Security Council and the President that we should not pursue this matter any further at this time.

Senator KERRY. Well, what changed in a year? I mean, I take it other than being miffed at the delay, what was substantively different?

Mr. BLOCH. No, I don't interpret it as being miffed at the delay.

Senator KERRY. What was substantively different? Why would we issue the invitation, and it was cleared, and then when it comes

back, we review it and we say, no, we don't want to even honor our own invitation?

Mr. BLOCH. Well, I think perceptions change, obviously. A better understanding of—

Senator KERRY. Defense Department perceptions. Is that correct? Defense Department perceptions.

Mr. BLOCH. Yes, Defense Department perceptions certainly.

Senator KERRY. What security could have been affected by a joint, even multi-lateral in this case, drilling effort? It even is more surprising to me, given the participation of all these other countries.

Mr. BLOCH. Well, it has to do with the access to equipment that is located on the ship, procedures for deep sea drilling activities, knowledge about deep sea drilling activities and so forth. The ship which the Foundation operates under contract, is a most advanced ship. You compare it to any ship that—

Senator KERRY. Didn't we know that when we issued the invitation?

Mr. BLOCH. Yes, we did. I said perceptions change over time.

Senator KERRY. Whose perception changed here is what I am getting at?

Mr. BLOCH. Well, there was obviously strong objection from Defense.

Senator KERRY. From the Defense Department.

Mr. BLOCH. Sure.

Senator KERRY. Now, in January of 1986 NSF approved—I am going to go a little bit over here so I can try to end my round this time. And I will give equal time over here, and then we will have to move on to the next panel. I will have to submit, incidentally some questions in writing. There are a host of issues here. We could go on for hours obviously, and we do not have time to do that.

But in January of 1986 you approved a \$500,000 grant to fund three programs at the International Institute for Applied Systems Analysis in Vienna. Then on March 27 of this year you were instructed by the National Security Council not to spend the money. I take it Oliver North did not call you, but obviously somebody over there did.

And I wonder why this takes place. I mean, isn't this an unwarranted intrusion in a sense by the NSC into the normal NSF procedures, which I think several leading scientists have alleged?

Mr. BLOCH. Well, you should recognize—and I know you do—that the National Science Foundation is part of the Executive Branch of the government. And therefore, when things are being debated and disputed, and when things are under scrutiny, there are many different viewpoints that come to the foreground.

And being part of the Executive Branch, obviously I do not consider the NSC as an intrusion. I think they have every right and need to look at it. We do not look at it from the viewpoint of national security. That is not our job. Our job is to look at it from the viewpoint of scientific merit and what it could do to the scientific knowledge base of the U.S. But there are other viewpoints in the Federal Government.

Senator KERRY. What was the reason for the decision?

Mr. BLOCH. Well, it was felt that we would get more out of it if we had a one-on-one relationship with the Soviet Union even in the same areas. We received a communication from the NSC which said why don't you take that money and put it into bilateral programs between the U.S. and the Soviet Union. It was felt that that would be a better allocation and appropriation of the funds than putting it into one particular institute.

Senator KERRY. Is that being done?

Mr. BLOCH. We are pursuing that. By the way, I also must say that the ruling from the NSC only applied to the 1986 proposal for IIASA. It does not apply to a new proposal which we are in the process of reviewing right now.

Senator KERRY. Last question. You were recently quoted in *Science* magazine as saying—and I quote you—"If all we are doing is the individual research grant approach to science, then I think this country is going down the drain." Can you explain what you meant by that?

Mr. BLOCH. Well, I probably did not quite say it as colorfully, but maybe I did.

What I wanted to say—

Senator KERRY. Well, I hope you did.

Mr. BLOCH. What I wanted to say was the following. And by the way, it was in relationship to the science and technology centers.

If the Foundation is only being looked at as supporting individuals, or would only support individual researchers on an individual basis, and not support centers as we have been doing for a long time and now want to step up and improve—then I think we are not fulfilling our role. Science is very complex. It is getting more complex. It is getting more multidisciplinary. More instrumentation is required. It is getting more expensive. And looking only at one way of doing science, namely—and I will exaggerate the case—the inventor or innovator or researcher locked up in his own laboratory not communicating with anybody else—if that is our model of science, then I think we are losing the ball game. That is what I had in mind.

Senator KERRY. Thank you.

Mr. BLOCH. There is a whole continuum of how to do science, and we are dedicated to the fact that we are dealing with that whole continuum and applying the right approach where it has merit.

Senator KERRY. Senator Pressler?

Senator PRESSLER. Thank you. I am very interested in the continental drilling program. And a few years ago, Dr. Papike from the School of Mines came into my Rapid City field office and suggested we have some legislation. We had a bill last year, and we are introducing another one next week. But the School of Mines in South Dakota is very active and interested in that.

How much does the NSF plan to spend on the atmospheric sciences and continental drilling programs for fiscal year 1988?

Mr. BLOCH. You put in atmospheric sciences in addition. Let me focus on the drilling program.

Senator PRESSLER. Okay.

Mr. BLOCH. The drilling program itself has something like \$7 million requested in 1988 for the drilling itself.

In addition to that in the earth sciences area, particularly in what is called the Continental Lithosphere program—we have about \$18 or \$19 million. And a lot of that is needed in support of drilling, and drilling is needed in support of that. So, you really shouldn't pull it apart.

Let me mention one thing. We had quite a bit of money planned this year in 1987 for continental drilling but because of some earmarking in Congress, we were unable to carry out our plans.

Senator PRESSLER. Now, as I understand it, NSF plans to spend approximately \$30 million for ocean drilling and only \$7 million for continental drilling. Is that correct?

Mr. BLOCH. That is about right, yes.

By the way, the \$30 million on ocean drilling is the total amount that is going into ocean drilling. And some of that money comes from foreign sources like Japan and France that I mentioned before. So, our own contribution is about \$23 million, \$24 million for ocean drilling.

Senator PRESSLER. What are the benefits of continental drilling to the United States? What are we trying to accomplish?

Mr. BLOCH. I think the first thing is to have a much better knowledge of the earth and its development and the structure that underlies the surface. So, I think it is general understanding of earth science so that you can later derive benefits in terms of finding out how to drill for minerals, how to exploit some of the resources that are in the earth.

I would give you a similar answer on ocean drilling also—to get a better perspective on how our oceans have developed and have been modified and how the earth has developed and modified.

Senator PRESSLER. I think the Russians are a little ahead of us, aren't they, in continental drilling? They have two or three projects that I have heard about.

Mr. BLOCH. I think their effort has been bigger than ours for many years. No doubt about it. They have a very big hole that they are drilling or have been drilling with mixed success, but nevertheless they have been at it for a long time and at a higher intensity. Yes.

Senator PRESSLER. What do you foresee in the future in terms of continental drilling? It is at \$7 million this year. Do you foresee it going up to \$20 million or \$30 million, or if you could do an ideal program, what would you foresee in the future?

Mr. BLOCH. It all depends on our total budget.

Senator PRESSLER. True. But let's say you had a free hand here. What would you do?

Mr. BLOCH. If I had an infinite supply of money, God knows where it would go. We have plans to increase that particular activity. In fact, the whole geosciences area is one of the big beneficiaries of a doubling of the budget. So, I could see the continental drilling program go to something like \$15 million, \$16 million, \$17 million easily.

Senator PRESSLER. Now, I know that NSF plans to double its budget in the next five years. Would that include doubling the continental drilling programs?

Mr. BLOCH. Well, I'll give you the same answer. Doubling the Foundation's budget does not mean that every element of the

Foundation's budget will be doubled. We have to set priorities. But the geosciences in total—atmospheric sciences, ocean sciences and earth sciences—are in for a major increase, yes. How it divides up, I would not want to say.

Senator PRESSLER. In the future does NSF plan to establish a drilling science and technology center as part of its research centers program?

Mr. BLOCH. Well, that is certainly a possibility. Again it depends on what kind of proposals we get for the science and technology centers and how they fare in the merit review process. But that is certainly one of the topics. The whole ocean sciences area is a topic for that as are many of the other sciences.

Senator PRESSLER. Turning to what is going on, I am told that over half of our graduate students in engineering are now from abroad. What impact will that have in the long term? Of course, in some ways you could say maybe we are getting a lot of engineers who have been educated in the U.S. and they will be friendly to us, although sometimes just the opposite is true. But why do few of our own students choose science or engineering as a career?

Mr. BLOCH. Well, that is a perplexing kind of an issue. I would say that there is not one reason. There are many reasons for that. First of all, many of our students are not moving on towards a Ph.D. degree because they can see economically that they can do better by joining industry or a service industry or a manufacturing industry or what have you. So, a lot of people are dropping out after the undergraduate or masters degree because they see the potential for economic success in the industrial area. That is certainly true in some of the forefront fields like computer science, and that is why you have a shortage of Ph.D. computer scientists. It is certainly true in many of the engineering areas such as electrical engineering and mechanical engineering. So, that is one reason.

The second reason is the facilities problem that we discussed before along with the instrumentation problem. For somebody who wants to do research, many times he can do that better in industry where there is more modern equipment available. That has certainly something to do with it.

Those are the two main reasons that I would identify.

Senator PRESSLER. Many foreign nationals participate in programs that NSF funds. Is NSF diverting funds to foreign nationals that could be used to start programs that interest U.S. students in science?

Mr. BLOCH. Well, I need to make three points on that. First of all, your number is absolutely correct. About 60 percent of the Ph.D. graduates in engineering are foreign nationals, but I want to remind you that a majority of those people are staying here and are joining the work force. So, it is not a loss to the country. In fact, we would be in very difficult situations if these people would not study here and would not stay here. We would be in a worse situation than we are today.

Secondly, some of our programs such as the Graduate Fellowship Program require that you be a citizen. Our PYI program, Presidential Young Investigator program, requires that you are a citizen or that you have a permanent visa.

Now, where we are supporting in an indirect way a lot of foreign students is in our grant programs, because who is a post-doc or who is a graduate student is determined at the local level by the principal investigator. So, indirectly yes, some support goes to foreign students. But in the concentrated programs that are aimed at attracting more people to the study of research, we put the provision in of either a permanent visa or citizenship.

Senator PRESSLER. What plans are for separate atmospheric sciences. We have one of our universities that is quite interested in atmospheric sciences. What are your spending plans and your projections on the atmospheric sciences side?

Mr. BLOCH. I think it is in the order of about \$70 million, \$80 million. I am not absolutely sure, but I will give it to you for the record. I will give you the exact number for the record.

[The following information was subsequently received for the record:]

The fiscal year 1988 NSF Budget Request to the Congress for the Atmospheric Sciences Subactivity is \$106.7 million.

Senator PRESSLER. I look forward to meeting with you again. I am determined that my State will get more involved in the EPSCoR thing. I have been working closely with the governor and with our delegation on that issue, but also would like very much to get you together with our university presidents so we can—although you certainly cannot coach a state, you have got to keep the integrity of the program, so to speak.

But I think that when we talk about industrial competitiveness, I was recently in eastern Europe and even the countries there talk about competitiveness. Of course, competitiveness is a lot of things. It can be knocking out golden parachute agreements that are wasteful for executives. It can be wasteful labor agreements. It can be failure to agree on product liability laws which make our products more expensive. It can be lots of things. It can also be a lack of keeping up in technology. And I think that is why this hearing is so important. But also I think that small business and small universities sometimes provide innovation.

I might just ask one more of the prepared questions, and that is about small business. Does NSF have any programs to include small business in research center activities?

Mr. BLOCH. Well, first of all, we have what is called the Small Business Innovation Research Program which is a fairly sizable program. About 1.2 percent or 1.25 percent of our total funding goes into that. We have made a deliberate attempt—and by the way, we just had a meeting of industry participants in the various Engineering Research Centers, and there were a large—I won't say a large number, but a significant number of very small companies that showed up for that and that are working with some of the Engineering Research Centers. We are encouraging the Centers to reach out to small companies, not just to the big ones. I think as much as we can, we are furthering that effort.

Senator PRESSLER. I think that most of the innovation that has occurred in business has come from small business—most of the research and improvements. I also tend to think, but cannot prove that a lot of very high quality scientific research is sometimes done

at smaller institutions that might not be the boys on the block, so to speak. No pun on your last name here, but it is something that I think we have to work on. And I think that our competitiveness as a nation would be improved if small universities are more involved in the process.

I thank you very much, and I look forward to working with you.

Senator KERRY. Thank you very much, Mr. Bloch. Thank you, Senator.

I wish we could have gotten into some questions on the super-computer in the Antarctic program. I would have liked to have asked you some things about the research center development and relationships and the science centers, et cetera, not to mention the Federal commitment to basic research and so on. There is just a host of information and questions that are swirling around on this whole subject matter.

But I do want for the record to pursue some specific questions in terms of the reauthorization as to how many centers are going to be in place, when and how you intend to allocate some of the money, et cetera. So, we will submit those in writing and try not to burden you too much with that.

And I thank you very, very much for bearing with us and for coming up here today and for your leadership on these issues. It is very, very important.

TESTIMONY OF
MR. ERICH BLOCH
DIRECTOR, NATIONAL SCIENCE FOUNDATION
BEFORE THE
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE
OF THE
COMMITTEE ON COMMERCE, SCIENCE, & TRANSPORTATION
UNITED STATES SENATE
THURSDAY MAY 28, 1987

MR. CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEE:

Good morning. I am glad to have the opportunity to provide an overview of the National Science Foundation's budget proposals for 1988, to discuss their relation to the nation's economic competitiveness, and to discuss a few additional topics of particular interest to this subcommittee.

First, let me express appreciation for the continued support that this subcommittee has shown for the importance of basic research in science and engineering. Your understanding of the links between research, education, and the welfare of our nation has been demonstrated by your willingness to recommend the needed investments in these areas which are important to advancing our economic competitiveness position.

It is high time that economic competitiveness moves to center stage. For too long we have tended to see the source of our economic problems as the result of unfair trade practices, or low wages in other countries, or unfavorable exchange rates.

Recently we have realized that if we want to compete successfully as a nation, the most important thing is to stay ahead of our competitors in continually generating new ideas through basic research, and turning them into high quality, innovative products and services for the market place. Many forces must come together to achieve economic competitiveness, but prerequisite is a viable infrastructure that is capable of educating our people and generating new knowledge.

Basic Research and Competitiveness

Colleges and universities are the principal instruments for development of these assets. They provide ideas and new knowledge for the products that we need to compete in high-technology areas, and the concepts and ideas that can raise productivity in low-technology manufacturing and service industries.

In fact, technological innovation achieved through research has been responsible for nearly half of all productivity gains since World War II. Research results can take their place side by side with economies of scale and other productivity enhancement parameters.

Many of NSF's programs can be directly tied to these driving forces: robotics, engineering research centers, biotechnology, materials research, education of future scientists and engineers, and many more. Seeking productivity through research and technological innovation is the way we should enhance our position in international and economic competitiveness. It is far preferable to reliance on trade barriers or other protectionist measures.

The Science and Engineering Enterprise

The science and engineering research base on which we depend consists of three elements: people, facilities, and equipment. Of the three, people are by far the most important. Well trained people are the source of the ideas and the knowledge which make technological innovation possible. A dynamic, productive economy demands a steady flow of new ideas and well-educated people to generate successful products.

Adequate facilities and equipment can be obtained relatively quickly -- it only takes money. The creation of a scientist or engineer takes many years--the process begins in the precollege years and continues through undergraduate and graduate training.

The length of time this requires makes it imperative that we continuously attract the most talented young students into science and engineering programs. Interruptions in this process take many years, even decades to overcome.

We cannot depend on market demand to ensure an adequate supply of scientists and engineers, for the market fluctuates much too

rapidly. The educational system cannot respond quickly when demand goes up, and finds itself producing surpluses when demand is down.

The Role of NSF

The government's ability to affect our competitive position is limited, since for good reasons much of the initiative and responsibility rests with the private sector. There is one area, however, in which the government's role is both necessary and clearly beneficial: the support of education and basic research.

That is why the National Science Foundation plays an increasingly critical role in the national quest for economic competitiveness. NSF does this by providing linkages among the vital elements of the science and engineering enterprise:

- o NSF not only supports research, but education;
- o It not only support basic research in the sciences, but also in engineering;
- o It supports the nation's top research universities, but reaches out to undergraduate institutions, high school and elementary schools as well; and
- o It does not operate in isolation but demands the active involvement in both planning and funding of private sector entities, state and local governments, and universities themselves.

The FY 1988 Request

Our budget request for Fiscal Year 1988 is \$1.893 billion. That is a substantial 16.7% above our appropriation for the current year. Of equal importance, the Administration is committed to increases at a rate that will double our budget, to a level of 3.2 billion dollars, by 1992 (Chart 1).

These increases, projected over a five year period, establish a strong base from which to expand support for education and university basic research and plan for the future. This is a major departure from the past. It reflects the need to rebalance our effort in research and development. This cannot be done in one year alone. It also reflects the nature of education and

research--many of the proposed programmatic thrusts are spread over many years, even decades. Stability of funding commensurate with the time horizon of programs and initiatives allows for much better planning.

NSF's budget request should not be judged in isolation. It must be considered as part of the total Federal research and development budget, in fact as part of the total U.S. research and development effort (Charts 2-4).

Since 1980, federal support for research and development has nearly doubled, going from \$33 billion in 1980 to about \$63 billion in 1987. The fraction of the civilian-oriented effort devoted to basic research has risen in that time from about 26% to about 39%. With strong bi-partisan support, the overall budget for the Foundation rose 66% between 1980 and 1987, ending a long period in which it was essentially flat.

These actions have been beneficial; but, we are continuing to experience serious problems:

- o Basic research is dropping as a proportion of total federal R&D. It is also shrinking in the private sector (Chart 5).
- o We see increasing research competition from our trading partners (Chart 6).
- o We see shortages of scientists and engineers developing in some fields.
- o Our production of scientists and engineers is not keeping up with that of our international competitors. And,
- o Facilities and instrumentation in universities need modernizing.

We can only conclude that a significant increase in education and basic research support in our universities is needed.

Our budget proposals for 1988 are focused on dealing with these issues and giving a renewed emphasis to basic research and support for universities.

Three major themes are emphasized in this budget:

- o Education and human resources;
- o Basic science and technology centers; and
- o Disciplinary programs and facilities.

Education and Human Resources

The first theme is education and human resources. The nation's science and engineering base -- the source of our ability to do basic research and to develop new technologies -- is made up of people, equipment and facilities. Of the three, people are the most important.

I do not need to recite the findings of several recent national studies and international comparisons which highlight alarming shortcomings in our education infrastructure, and in science and mathematics achievement among our students. And we know the demographic data that show us a future with proportionally fewer young people, our most basic resource.

We must act to address these serious concerns about the quality and quantity of the talent pool we need to sustain a vital scientific and technical enterprise in this nation.

The National Science Foundation proposes significant growth in support for education and the development of human resources, from \$182 million in FY 1987 to \$273 million in FY 1988.

Attention is given to the precollege, undergraduate, and graduate education areas. NSF has different responsibilities at each of three areas of the educational spectrum.

In precollege education, the feeder for all science and engineering talent for the country, the center of gravity of support and policy is in the thousands of localities across the country, the state governments, and--on the federal level--at the Department of Education. Yet our influence can be large. Our programs are designed to catalyze, to demonstrate, and to mobilize interest from other participants. The Foundation's resources are small compared to the total resources available and need to be judiciously applied. For FY 1988, the President's mandate that NSF, in conjunction with the Department of Education, address mathematics, science, and computer literacy for the country's children will be a major focus.

Undergraduate education in science, mathematics, and engineering has been singled out by the recent report to the National Science Board as demanding major attention. NSF's role will be one of focusing on:

- o Research experiences for undergraduate students and faculty as part of its disciplinary research projects and centers;
- o Curriculum development, beginning with calculus and engineering; and
- o Instructional and research instrumentation for use by undergraduate faculty and students.

This is a new approach for NSF with respect to organizing our support for undergraduate research and education in science and engineering. All directorates will have a role and the effort will be coordinated for the Foundation as a whole by the Science and Engineering Education Directorate.

Graduate education has always been a major focus of the Foundation through its prestigious Graduate Research Fellowships Program and its support of graduate students through ongoing research awards. Support beyond the graduate level has included postdoctoral research associates, postdoctoral fellowships where special needs exist, special seminars and conferences, research initiation efforts, and the Presidential Young Investigators program.

Throughout the planning process and the development of the budget request before you, focus has been on balance across the educational spectrum to attract, educate, and retain the technical personnel we need for our future. We have used the principles of excellence and opportunity for participation by all our citizens, regions, and institutions to build a strong, comprehensive approach.

The following table shows the distribution of funds for this effort:

EDUCATION AND HUMAN RESOURCES

Undergraduate	\$ 68.0 Million
Instrumentation/Laboratory Development	22.0*
Research Experience for Undergraduates	18.0*
Faculty Enhancement	11.0*
Curriculum Development	7.0
Research in Undergraduate Institutions	10.0
Other Human Resources	\$ 205.0 Million
Precollege	68.0
Graduate/Postdoctoral	54.5
New Investigators	52.0
Broadened Participation	30.5

* Planning estimates. Final distribution will depend on proposal pool. Some projects may combine efforts for laboratory instruction, faculty and student development.

Under this effort, existing programs will continue, and expand, and new activities will be supported:

- Precollege emphasis on teachers, materials, advanced technology, and informal science education continues. New activities for high ability high school students will be implemented.
- Support for undergraduate activities more than doubles, with new activities for faculty and curriculum development, and significantly enhanced programs for instrumentation and students.
- 200 additional new Graduate Fellowships will be awarded, and the number of Presidential Young Investigators will increase by 200.
- New activities will be introduced to increase the number of women and minorities participating in science and engineering.

I want to emphasize that this effort in education and human resources will be supported throughout the Foundation. Over the past three years, the Foundation has placed increasing emphasis on addressing significant cross-cutting issues through all its programs. We have developed coordinating mechanisms, and

established tracking and monitoring systems. This cross-directorate approach will be followed in the proposed activities for education and human resources.

The Science and Engineering Education (SEE) Directorate will continue its primary emphasis on precollege education, instructional laboratory equipment for undergraduate institutions, and the prestigious program for graduate fellowships (Chart 7). It also has the prime responsibility for bringing the President's mandate referred to above a reality.

I firmly believe that the Foundation's disciplinary research directorates must be responsible for the health of their science and engineering disciplines -- including concern for the underlying education and human resources infrastructure. The most effective activities in this arena will reflect the particular needs of specific disciplines and research areas. Therefore, the undergraduate initiatives, like many of the efforts focused on participation by minorities, women, and the disabled, are distributed across NSF, with central monitoring and fiscal control.

We have already seen the success of this approach in the program for Research in Undergraduate Institutions. The new program for Research Experiences for Undergraduates, introduced just last December, is already drawing enthusiastic response.

It is also important to recall that in addition to these focused efforts for education and human resources, the Foundation continues its substantial support for undergraduate and graduate research assistants on NSF research projects -- fostering in another way the critical link between education and research. In FY 1986, more than \$115 million supported over 3,000 undergraduate and 12,000 graduate students in this fashion (Chart 8). This support will grow to an estimated \$145 million in FY 1988 through proposed increases for science and technology centers and basic disciplinary research programs.

Basic Science and Technology Centers

The second theme is the establishment of basic science and technology centers. These are university-based, multidisciplinary research centers--each with strong industry involvement--working on problems that are scientifically important and can, in the long term, contribute to advancing our economic competitiveness. This is the program that the President announced in his State of the Union address.

The close coupling of industry with academic research that these centers provide has the potential to substantially improve technology transfer from research labs to industry and to the marketplace.

At the same time, these science and technology centers will play an important part in the education process because they involve students, both graduate and undergraduate, in research on important problems. The result of that research will find its way into improved curricula.

The proposed \$50 million increase will be applied to the establishment of new centers based on the proven concept of the engineering research centers. These would include additional ERC's, biotechnology centers, and centers for materials science, social and behavioral sciences, and computer and information sciences.

Disciplinary Research Programs and Facilities

The third theme of this budget is the steady improvement of the Foundation's traditional broad support for disciplinary programs and specialized research facilities. For these activities, we are proposing an increase of nearly \$100 million, with special focus on global geosciences, biotechnology, and materials science and engineering.

Solid support across all the disciplines is important because, by its nature, basic research is unpredictable; one cannot say in advance where a breakthrough with major economic importance will be found. But we know from experience that they will be found.

Let me give you an example of that that I found striking: a problem in basic research in astronomy a few years ago was to develop calculations that could determine the properties of objects that are occluded by the moon. No one could have predicted that this same process of calculation would become the basis of an important modern medical technology called computerized axial tomography: the "CAT" scan.

These jumps from basic research to applications can almost never be foreseen, but they have happened so frequently in the past that we can be confident of the ultimate value of the investment.

Now I'd like to discuss a number of topics of special interest--the NSF merit review system, achieving balance in the support of individual projects and large scale centers, and the Foundation's plans in FY 1988 for the U.S. Antarctic Program.

Merit Review

The Foundation is very proud of its competitive proposal review process. The core of this process is the judgment of qualified, experienced scientists and engineers in identifying promising, high quality research and education projects worthy of support. This system has been subjected to periodic examination by internal task forces and outside panels, including Congressional committees. It has been found to be remarkably effective and flexible, adapting to the changing needs of science and engineering, and incorporating improvements with respect to openness, accountability, equity, and impact on the research and education environment.

At NSF there are more than 200 individual programs managed by some 300 program officers, about a third of whom are on leave from their universities or other organizations. Program officers are recruited for their knowledge and experience and they interact constantly with the research or education community of which they are a part. They are experts in their fields and are well aware of the opportunities and needs in their areas. They administer the proposal review process and use its results to form the basis for their recommendations for support of projects. Their recommendations are, of course, reviewed by higher level officials, and if the award recommended exceeds \$1.5 million for one year's support, by the National Science Board.

NSF's review process includes participants from the broad community of highly qualified scientists and engineers--men and women, white and minority, large research institutions and smaller undergraduate-oriented colleges and universities, federal laboratories and industry, and from all geographic regions. We take the fairness issue very seriously and conduct an annual statistical analysis to identify real or apparent biases.

Since 1974, NSF has used four criteria for selecting projects: research performance competence, intrinsic merit of the research, utility or relevance of the research, and effect of the research on the infrastructure of science and engineering. The excellence of the science of engineering being proposed is THE major factor for selection. Once that has been established, the secondary criteria are used. In 1986 the NSF Advisory Committee on Peer Review chaired by Dr. Norman Hackerman, President emeritus of Rice University and former Chairman of the National Science Board, affirmed the fundamental health of the present system. Recognizing the evolution of the peer review process at NSF, it recommended adoption of the term "merit review" as a more accurate description of the present process.

In the last few years there has been an increase in interdisciplinary research proposals. This is a reflection of the growing numbers of research problems which require the combined expertise of scientists and engineers from several disciplines. Such proposals present special problems for a system which has traditionally been structured to handle proposals which are single discipline in nature. Different organizational arrangements for administration and different review procedures are required, as was the case with the Engineering Research Centers Program. The process we instituted involved a multi-stage, interdisciplinary review of ad hoc panelists, a site visit team, and a final "blue ribbon" panel.

Monitoring Project Balance

One of the issues which has recently become of great concern, to many in the academic research community is that of balance among the various modes of support for research. As the area of multidisciplinary research has grown and as the cost of research equipment has continued to increase, we have seen a shift in the proportion of resources devoted to collaborative research projects. As this has happened, concern about the funds that go to individual investigator projects has been expressed.

The facts are that individual investigator awards constitute by far the largest portion of the NSF budget (about 60%), and reflect our commitment to maintaining the basic research capability of the Nation across the full spectrum of science and engineering disciplines. These awards promote flexibility and spontaneity which often foster scientific breakthroughs.

At the same time, much basic research over the past decade has moved in the direction of collaboration and concentration of resources. Much of this change is driven by the nature of scientific inquiry itself rather than just the increasing costs of doing forefront research.

Technologies such as satellite communication and large scale computing and computational techniques enable scientists to work with data sets of greater size and complexity than ever before possible. The leading edge of modern scientific effort is more and more at the intersections of traditional disciplinary boundaries: astrophysics, biotechnology, atmospheric chemistry, materials science and engineering for examples are emerging "fields" which require expertise from more than one discipline.

The fraction of the NSF budget devoted to collaborative research has been growing over the past several years in response to the trends noted above. In many cases, scientists who would have worked alone or with a graduate student or postdoc now find themselves interested in problems which require association with other investigators, and the use of large scale facilities and specialized instrumentation.

Centers such as those initiated under the Engineering Research Centers program are a natural evolution of the trend toward interdisciplinary collaboration to address complex and urgent science and engineering problems. In addition, centers provide unique opportunities for education and technology transfer as well for involving the private sector, states and localities, as active partners.

Let me assure you that this matter of balance is of great concern to the Foundation. It receives careful consideration at every level, from individual program to senior management and the National Science Board, and is a major element in the deliberations of our advisory bodies. This year one of the National Science Board's Task Committees is specifically devoted to examining the centers/individual support modes, including the issue of arriving at a proper balance between them.

The continuing rebalancing between centers, groups, individual grants, instrumentation, and facilities is driven by the demands of science and engineering, the emergence of new disciplines and research approaches. The current proportions among these various modes reflect our judgments about the dynamic forces in today's research as well as the fundamental relationships which underpin the long term health and vitality of the science and engineering enterprise. As in all changes, what is the emerging golden age to some, is threatening to others.

U.S. Antarctic Program

The U.S. Antarctic Program requires separate examination because one of its major goals differs from those general to NSF programs. The Foundation budgets for and manages this program which provides an active and influential U.S. presence in Antarctica. Research continues to be the expression of the presence, which also involves three permanent stations including one at South Pole, a heavy airlift capability extending the range of research beyond coastal stations, and a shipborne research capability. The influential U.S. presence thus provided, aids in maintaining the Antarctic Treaty under which conflicting territorial claims of several nations, are held in abeyance.

While the science in Antarctica contributes to international objectives, its quality is high and its content fits well with the geoscience objectives involved in looking at the earth and its environment as a system. Antarctica has a major influence on world weather and climate. Also, because of the unique character of the region certain phenomena that appear there may provide early warnings with world-wide implications. The seasonal ozone depletion phenomena may fall into this category. Measurements since 1957 from a U.K. station first indicated this major springtime depletion of stratospheric ozone, which reflects dangerous solar ultraviolet radiation. Much was learned of this phenomena in the first U.S. National Ozone Expedition that was flown to Antarctica late in the austral winter of 1986. More is expected from the second expedition this year. These expeditions are made possible by the station and airfields at McMurdo and the ski-equipped LC-130 aircraft that were existing components of the U.S. Antarctic Program.

It is imperative to extend research capabilities in other areas as well. One means is the lease and outfitting of an icebreaking research ship included in the FY 1988 Request. This ship is intended as a science replacement for the former Coast Guard icebreaker GLACIER. It is expected to extend science capabilities by being available for year-round research across the ocean sciences. It may prove to be a platform for atmospheric sciences, including ozone research as well, and add long neglected capabilities in geology and geophysics.

Much of the balance of the FY 1988 Antarctic program increase will go to maintaining and improving the infrastructures of planes, ships and stations that will allow U.S. antarctic science to continue and will increase its effectiveness. These activities are a major importance to U.S. and in some cases of world-wide interest.

Summary

In summary, the NSF budget for Fiscal Year 1988 and future years will allow the Foundation to improve research and education in our universities and colleges in very important ways through:

- o basic science and technology centers;
- o mathematics, science, and engineering education at all levels of the educational pipeline;
- o broader participation of institutions and underrepresented groups;
- o cooperation between federal and state governments, industry, and academia; leveraging taxpayers' dollars in the process; and,
- o transfer of research results from universities to industry.

Mr. Chairman, all these activities are important for the long term economic health of our nation. Through them, the Foundation will make significant improvements in research and education at our universities and colleges.

Even more important, the Administration's commitment to doubling of the NSF budget will keep education and basic research in science and engineering on a steady upward track. I believe strongly that nothing is more important for the long term economic health of our nation. I look forward to working with you and with the entire Congress to make sure that these proposals are turned into actions.

NATIONAL SCIENCE FOUNDATION OBLIGATION TRENDS

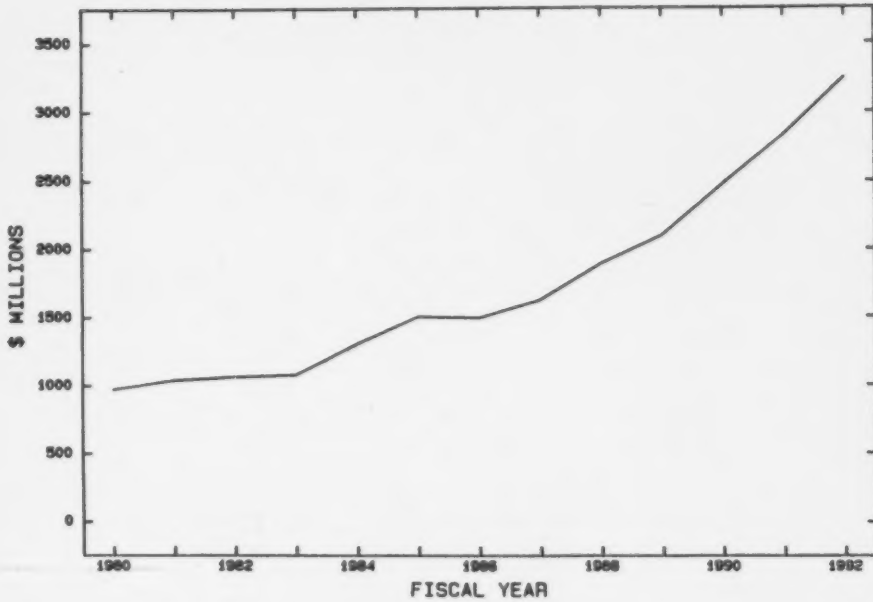
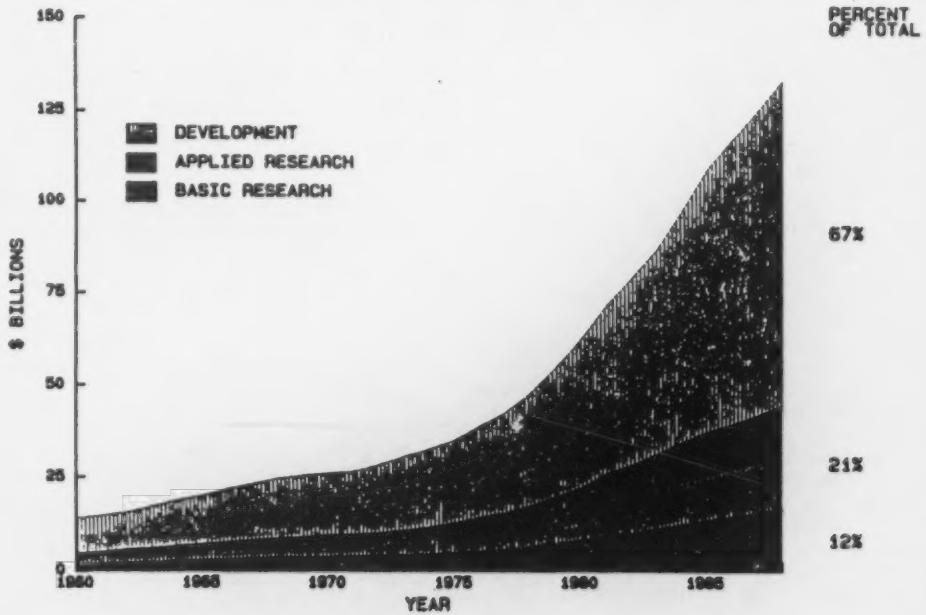
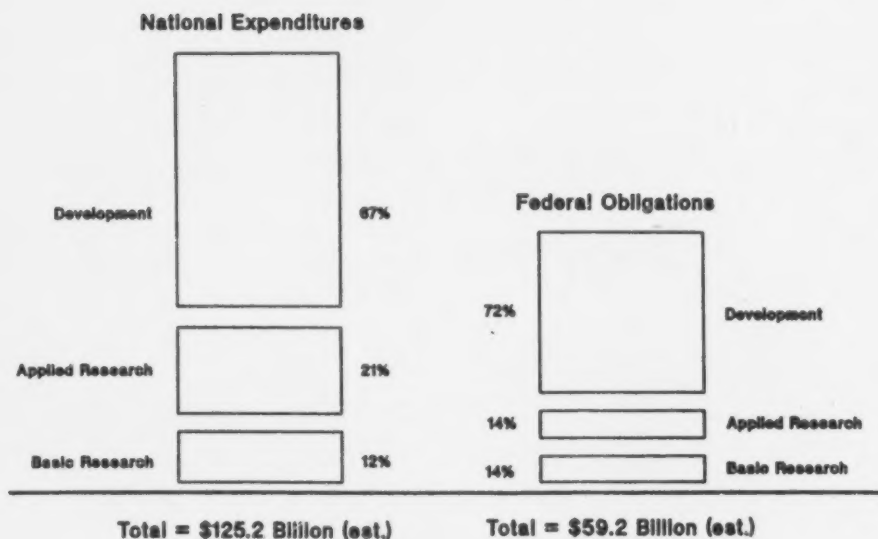


CHART 2

NATIONAL EXPENDITURES FOR RESEARCH AND DEVELOPMENT



Research and Development 1987



National Expenditures for Basic Research

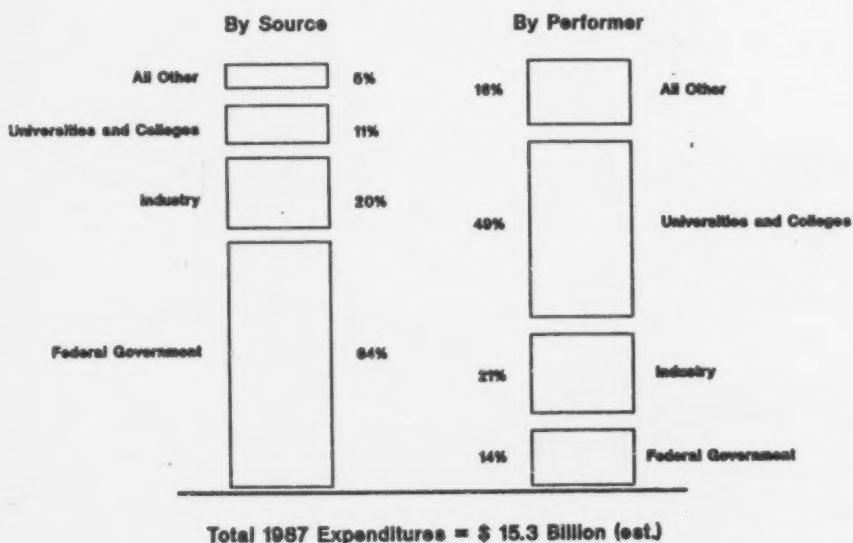


CHART 5

BASIC RESEARCH — AS A PERCENT OF TOTAL R&D —

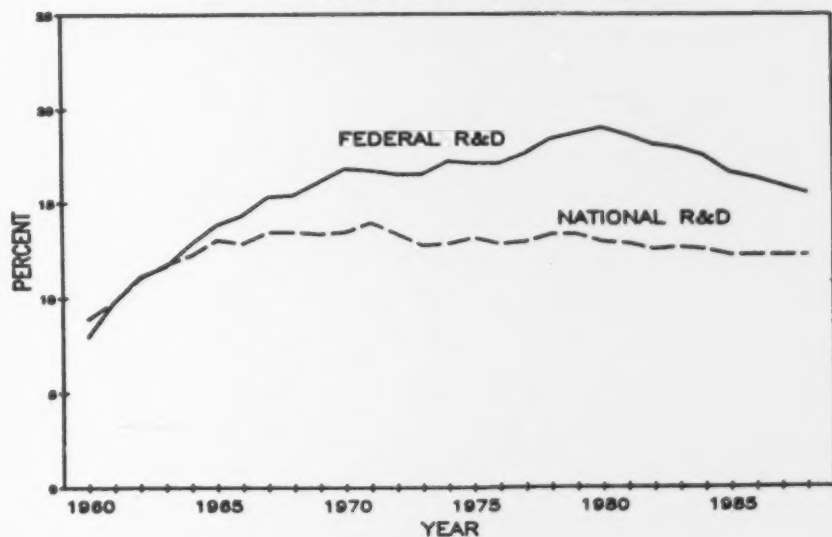
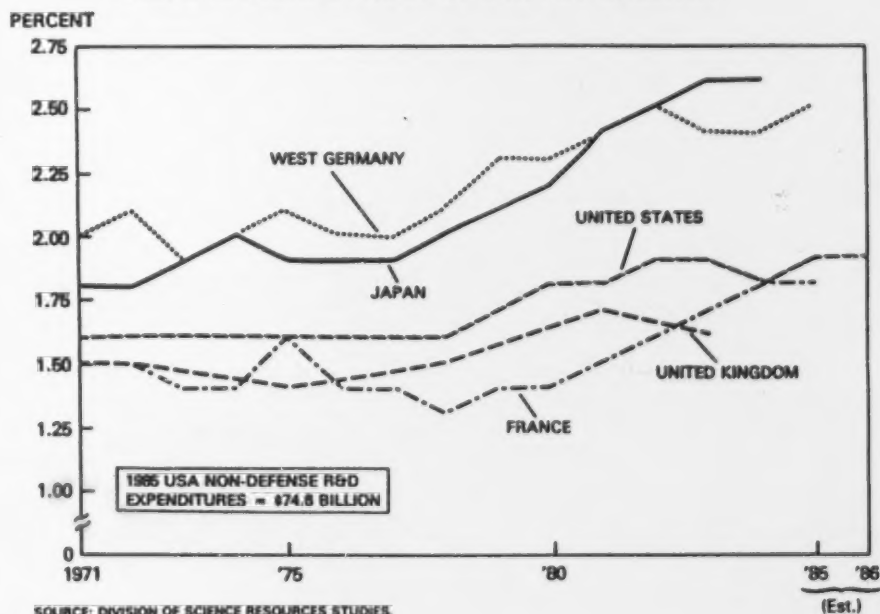


CHART 6

NON-DEFENSE R&D EXPENDITURES AS A PERCENT OF GROSS NATIONAL PRODUCT (GNP) BY COUNTRY



SOURCE: DIVISION OF SCIENCE RESOURCES STUDIES.

CHART 7

NATIONAL SCIENCE FOUNDATION
SCIENCE AND ENGINEERING EDUCATION DIRECTORATE
OBLIGATION TRENDS

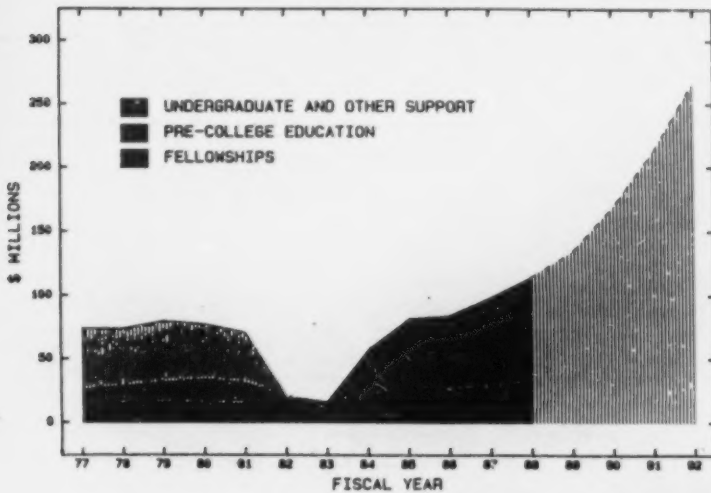
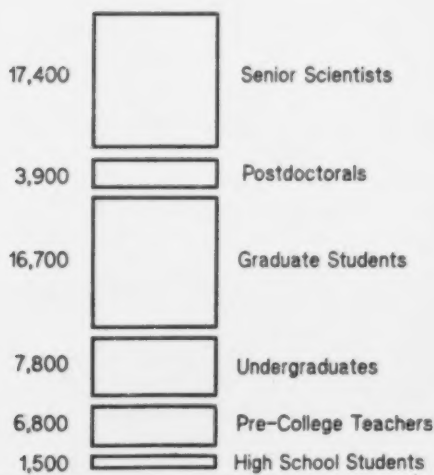


CHART 8

National Science Foundation
Support for Human Resources
In Science and Engineering

Fiscal Year 1988



Senator KERRY. I will ask the second panel members to take their places. And while they do, I would ask them to realize that we are going to run short on time, and I want to have time for questions. So, I am going to ask each of you to adhere to a five minute rule, and while I step outside here for one quick moment, you may want to collect your thoughts or do your editing. All testimony will be submitted in full for the record obviously. I will be right back.

[Recess.]

Senator KERRY. Why don't we start with Dr. Widnall, and we will just go from my right to left proceeding down. Thank you all for your patience, and thank you for being with us.

STATEMENTS OF DR. SHEILA E. WIDNALL, PRESIDENT, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, PROFESSOR OF AERONAUTICS AND ASTRONAUTICS, MASSACHUSETTS INSTITUTE OF TECHNOLOGY; DONALD G. WEINERT, P.E., EXECUTIVE DIRECTOR, NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS; DR. DAVID WAUGH, VICE CHAIRMAN, ENGINEERING DEANS COUNCIL, AMERICAN SOCIETY FOR ENGINEERING EDUCATION, AND DEAN, SCHOOL OF ENGINEERING, UNIVERSITY OF SOUTH CAROLINA; DR. BERRIEN MOORE, DIRECTOR, INSTITUTE FOR THE STUDY OF EARTH, OCEANS AND SPACE, UNIVERSITY OF NEW HAMPSHIRE; DR. ROBERT M. ROSENZWEIG, PRESIDENT, ASSOCIATION OF AMERICAN UNIVERSITIES

Dr. WIDNALL. Mr. Chairman, members of the subcommittee, we thank you for the opportunity to express our views on the NSF budget authorization.

I would like to clarify my role in making these comments. Although I am a professor of aeronautics and astronautics at MIT, and now I learn I am an Ivy Leaguer, which sounds great, I am submitting these remarks as President of the American Association for the Advancement of Science, an organization of over 130,000 scientists and engineers drawn from very broadly across the various fields of science and engineering. We, of course, are the publishers of the *Journal Science*.

I have submitted rather extensive testimony covering a number of the areas that were discussed this morning, as well as quite a number of areas that your staff had specifically asked us to respond to. I think in the interest of time I will simply shorten my remarks to try to touch on a few areas that perhaps were not talked about this morning.

At the close of the very eloquent opening statement by our Chairman, I think I felt we could all go home. I think we are in very solid agreement with you on the importance of the area that we are dealing with this morning and on the contribution of science, technology education to our economic competitiveness. In fact, I will shorten those areas because I think we all recognize those.

Let me concentrate on some things that perhaps have not been talked about. However, first I would like to say that we strongly support the overall growth rate reflected in the NSF budget request, a proposal to double over the next five years. And in fact, in

the context of our overall national research requirements, this is not an overly ambitious objective.

One way of looking at this is from the viewpoint of an individual researcher, which I am. Currently we see grants to individuals under the NSF program which are on average supporting one-half graduate student. Raising this support to an average of graduate student per NSF individual research grant over a period of five years, as well as providing funds for the growth of the engineering research centers and initiating the science and technology centers, seems to be quite a reasonable and not overly ambitious goal.

The proposed rate of growth in the NSF budget is a major step in the direction of reversing some of the problems associated with a level plateau of investments in research from the late 1960s to the late 1970s.

Let me just say a word about research priorities. You requested that we address the areas of research priorities, and I will do so only in quite general terms. I think this has been mentioned this morning. Advances across a very broad front in science and engineering are required to form the basis of a technological society. New opportunities and breakthroughs can come from quite unexpected sources as has been demonstrated by the superconductivity breakthrough which has become front page news. Even *Time* magazine did a whole issue on it. It sort of blows my mind.

This diversity arises from the fact that in our system priorities in fundamental science and engineering areas are set in a very complicated interplay among Federal program managers and individual researchers. We believe that this is one of the major sources of strength to the American science and engineering system. It is not to say that no improvements are needed and it may well be that we are less speedy nationally in responding to some major opportunities with a critical mass of resources.

In contrast, we see right before our eyes the more rapid reaction time by the Japanese in organizing themselves to take advantage of the breakthrough in superconductivity.

I suggest that this particular issue can serve as a test case for our very flexible system to see how we respond to this challenge. We know this is likely to be an important area. We see various segments of the government gearing up to deal with this problem, and I think we might at the same time watch how our system responds to this challenge and hopefully successfully.

I want to say a word about super computers because I think this is another area that is extremely important for our competitiveness. I will offer a perspective which stresses the importance of super computers as a major influence in the transformation of research in science and engineering. There is very strong rationale for NSF to support super computers in the research world, and I consider their role as major element in the support of U.S. science and engineering, and we strongly support congressional action in providing for a substantial increase in NSF's super computer program.

I think super computers are transforming the field of research and science. And I think it is important that the United States has a leadership position in this area. I also think it is absolutely vital that we retain this leadership position.

Universities are playing a very important role not only in the development of super computers, but also in providing a test bed for our industry on how to use these computers and development of new software. And one benefit of this test bed is that graduate students trained in university research will become excellent sources of trained manpower for our industry.

Let me switch briefly to talk about science, math and engineering education. And here I guess let me shorten it a little bit and just point out that we are following on the heels of quite a number of studies which have evidenced a lot of concern about our basic science and math education. Let me just say that we are very concerned at the small growth rate in the NSF budget for science and math education.

And I guess I would just want to close. Speaking as an engineer, I want to tell you that I strongly support the direction that NSF is moving with the engineering research centers and with the new initiative in the science and technology centers. I think these are extraordinarily important developments, and I think that this will provide us some mechanisms, which we have not had up to the present time, of really engaging the universities in some important national problems.

Thank you.

[The statement follows:]

STATEMENT OF DR. SHEILA E. WIDNALL, PRESIDENT, AMERICAN ASSOCIATION FOR THE
ADVANCEMENT OF SCIENCE

INTRODUCTION

We thank you for the opportunity to express our views on the Fiscal Year 1988 National Science Foundation Budget Authorization Request. I would like to clarify my role in presenting these comments. Although I am a Professor of Aeronautics and Astronautics at MIT, I am submitting these remarks as the President of the American Association for the Advancement of Science—an organization of 130,000 scientists and engineers and the publisher of the journal *Science*.

The specific areas addressed in this statement include some overview comments on the budget as well as that of the National Science Foundations; the link between investment in basic research and U.S. competitiveness; research priorities; super-computing and science; science, mathematics and engineering education; instrumentation, equipment and facilities and the health of university research; and individual vis-a-vis group or center research awards.

OVERVIEW COMMENTS ON BUDGET AS A WHOLE

First, we strongly support the overall growth rate reflected in the budget request. In the context of our overall national research requirements, it is not an overly ambitious objective. Another way of looking at the proposed growth is from the viewpoint of an individual researcher (such as I am). Currently we see grants which are on the average supporting one-half graduate student. Raising this support to an average of one graduate student seems to be a rather modest goal. We acknowledge the difficult set of questions facing the Congress in the context of the Gramm-Rudman-Hollings deficit limitations. However, the proposed rate of growth in the NSF budget is a major, if partial, step in the direction of redressing the problems associated with the level plateau of investment in research from the late 1960s to the late 1970s. To the extent that we differ from the program and budget proposals of the NSF, it is on priorities in a few areas. I hasten to add that the areas of agreement are large and the areas of differences are relatively small. It is in science and mathematics education areas that we find ourselves in less agreement than in others.

In taking a brief look at the overall budget for research and development, I would like to make several observations:

First, as in recent years, the dominance of defense and space R&D is still pronounced. While the issue of a defense-civilian balance in R&D is controversial, in

that strongly differing views are held about such things as "spin-off" effects of militarily-focused R&D, the subject cannot be ignored.

Some have observed that in comparison with the United States both Japan and West Germany spend a larger percentage of their GNPs on civilian research and far, far smaller fractions of their total R&D on defense programs. They then argue that under these circumstances it is no accident that they have two of the most advanced economies in the world. Others, just as firmly, assert that military R&D is a major driver of our economy and does not represent a "drain" on our civilian economy or our international economic competitiveness. Unfortunately, we are hampered by the fact that, to our knowledge, no major studies of the military-civilian R&D balance and its potential implications have ever been made.

A second feature of the overall budget for R&D is the very low—less than one percent—increase requested for all of basic research between FY 1987 and 1988. After taking out the "advanced appropriations" component for NIH of about \$1.7 billion to provide comparability with previous years, the comparison for the two years is as follows: FY 1987: \$9.0 billion; and FY 1988: \$9.1 billion.

LINK BETWEEN BASIC RESEARCH AND ECONOMIC COMPETITIVENESS

I do not intend to claim that the national underinvestment in research described earlier explains fully the state of our current economic problems domestically and internationally. However, I think a very strong case can be made that future research investments must be an important part of a total program for revitalizing our economy. Since you examined this topic at considerable length in hearings earlier this year, I will keep my remarks brief.

An easy way to do this is to provide our endorsement of the statement given to you by Mr. Erich Block on February 24, 1987 in your hearing on Science, Technology, and U.S. Competitiveness. There is absolutely no doubt that our past investments in fundamental science and engineering have led to major new industries; moreover, from current investments we can already begin to see the emerging contours of future industries based on advances across the board in science and engineering.

As we look to these future times in the environment of an increasingly competitive world, this is not the time to falter in our support of basic research—even in the face of the budgetary squeeze you and we are struggling with. As a nation we must avoid the not uncommon action on the part of various private firms which cut back their R&D activities in the face of sales or profitability drops.

In concluding this section, I would like to draw in part on several points in Mr. Bloch's statement—to which I referred earlier. A broad program to improve our overall economic strength and our ability to compete internationally must include at least the following elements: Strong support of basic research in science and engineering; an effective education system which will produce enough quality engineers and scientists as well as a wide array of other skills which will increasingly be needed by an advanced technologically-based society; adequate investment in research facilities and instrumentation within the federal government's laboratory complex and at universities; and provision for a legal and economic environment which encourages and enhances the linking of government-industry-university capabilities in the complex processes associated with the transformation of fundamental research into products, processes, new firms and new industries.

RESEARCH PRIORITIES

While you requested that we address the area of research priorities, I will do so only in quite general terms. Advances across a broad front are required to form the basis of a technological society. New opportunities and breakthroughs can come from quite unexpected sources as demonstrated by superconductivity which has become front-page news around the world.

Achieving this diversity arises from the fact that—in our system—priorities are set in fundamental scientific and engineering areas in a complicated interplay among federal program managers and individual researchers and research centers. We believe that one of the major sources of strength of American science and engineering research comes from this rather decentralized process.

This is not to say that no improvements are needed. It may well be that we are less speedy nationally in responding to major problems and opportunities with "critical masses" of resources than we ought to be. Let me be more specific. Long ago the need for such responses was recognized in the national security area by the establishment of the Defense Advanced Research Projects Agency (DARPA). Yet, we have no "civilian" counterpart to DARPA.

In contrast, right before our eyes is the much more rapid reaction time by the Japanese *national* response in organizing themselves to take advantage of the breakthrough in superconductivity during the past year. I suggest that this could be a test case for us in finding more effective balances between our diversity and decentralization on the one hand, and some kind of centralized guidelines and resource focusing on the other.

I would like to see a stronger role played by the Office of Science and Technology Policy in the Executive Office of the President in the overall research priority setting process. An important accompanying role would be to act as a catalyst in marshalling critical masses of resources for large, important issues on a timely basis. Recent positive examples of this kind are the roles performed by OSTP in establishing supercomputer programs and the Engineering Research Centers.

FUTURE OF SUPERCOMPUTING

Turning now to the subject of supercomputing because it is so crucial, I will offer a perspective which stresses the importance of supercomputers as a major influence in the transformation of research in science and engineering.

There is strong rationale for NSF support of supercomputers in the research world. I consider their role as a major element in support of U.S. science and engineering research. And we strongly support last year's Congressional action in providing for a substantial increase in NSF's supercomputing program.

I strongly support the arguments which have previously been presented to the Congress stressing the vital importance of supercomputing capabilities to the performance of high quality research in an increasing number of fields of science and engineering. And it is important for us to acknowledge the need to look at the acquisition of these capabilities in a national context—not just through the lens of the National Science Foundation. The Departments of Defense, Energy, and Health and Human Services as well as NASA are also involved in significant ways, as is industry. Supercomputing capabilities will be critical to enhancing and facilitating advances in research—from fundamental science to industrial and governmental applications, including national security.

In recent years the National Academies of Sciences and Engineering have been examining how the various fields of science and engineering have been changing. Many of these changes are affecting the directions, content and boundaries of traditional disciplines. I would add that supercomputers are already beginning to have significant transforming effects on the performance of research. These effects undoubtedly will continue to unfold and to have major impacts of the conduct and organization of science and engineering.

As I survey the supercomputer scene and its impacts, I think it is possible to say that quite clearly the United States has retained a leadership position. What is important is that we maintain the momentum which has been developed in recent years.

In concluding this section, I would like to make several summary remarks:

(1) Computers of all kinds, including large supercomputers and mini-supercomputers, are becoming crucial to making new discoveries and are increasingly central to advances in most fields of science and engineering.

(2) There is an immediate need to make supercomputers available to U.S. researchers as widely as possible.

(3) The advanced work station will become an important feature of research performance in the years ahead.

(4) Computer networks are required to link researchers via their workstations to supercomputers, to data bases, and to each other.

(5) The supercomputer programs—as supported by NSF, Defense, NASA and the Department of Energy—have acted as a spur and incentive for U.S. industry, in ways comparable to the federal government's support for early large mainframe computer development.

(6) Universities have played an important role not only in scientific and engineering areas related to supercomputers but also have provided a "test bed" service in assisting U.S. industry in the development of new ways to conduct, present and interpret research carried out on supercomputers. A specific feature of this "test bed" service is that graduate students trained in university research involved with supercomputers will be an excellent source of trained manpower for industry.

I hope the Committee will give its strong support to NSF's efforts aimed at establishing and building a strong supercomputer program. It is worth stressing that advances in supercomputing and networking are potentially among the greatest advantages to be gained in the performance of U.S. science and engineering relative to other parts of the world. Finally, in the industrial sector I should note that a

number of leading firms, such as MCI, AT&T and Bell Labs, see networking as a central feature of their strategy for achieving growth and success domestically and internationally in coming decades.

SCIENCE, MATHEMATICS AND ENGINEERING EDUCATION

In contrast to simply addressing budget numbers, we have chosen to present our views on science, mathematics and engineering education in a broader context.

THE SCOPE AND NATURE OF U.S. EDUCATION PROBLEMS

Others have described and verified the serious state of affairs in U.S. education and underscored the gravity of the associated problems. Numerous special studies and reports cover education generally and science, mathematics and engineering education particularly. To set the stage for the remainder of my remarks, I will provide a few key excerpts which capture several essential ideas.

First, in a recent 1986 report of the Carnegie Forum on Education and the Economy, *A Nation Prepared: Teachers for the 21st Century*, it was stated that: "The 1980s will be remembered for two developments: the beginning of a sweeping reassessment of the basis of the nation's economic strength and an outpouring of concern for the quality of American education. The connection between these two streams of thought is strong and growing."

Second, in a report to the President of the 1984 White House Conference on Productivity, *Productivity Growth: A Better Life for America*, it was observed that: "Without a literate, skilled, healthy, and motivated labor force, capital and technology cannot create a productive environment."

Third, in a 1983 report of the National Commission on Excellence in Education, *A Nation at Risk*, it was argued that: "If only to keep and improve on the slim competitive edge we still retain in world markets, we must dedicate ourselves to the reform of our educational system."

Finally, the Task Force on Education and the Economy, Education Commission of the States, said in its 1983 report: "It is our judgment that a high general level of education is perhaps the most important key to economic growth."

Clearly, education is increasingly seen, along with international business and trade, as a key area of concern in our search for solutions to the problems we associate with our diminished competitiveness. Perhaps it is no exaggeration, then, to suggest, as has the *National Journal*, that we have a large "education deficit" as well as a "budget deficit."

Our "education deficit" is across the board—in teachers and teacher training, in learning methods, in educational motivation, in school organization, in curriculum content and structure, and in educational research. A distinct part of this "education deficit" is in mathematics and science education where U.S. students perform poorly in international comparisons. All of this presents a grim picture and a worrisome outlook. However, before I go ahead with my discussion on specific aspects of science, mathematics and engineering education, I would like to offer several cautionary notes on how we proceed from here.

The range of problems is so broad and their roots so deep that we may be tempted to throw up our hands and say "let each school district or state worry about its own special problems. It's much too complicated to do so nationally." Yes, the states and the schools have a central role but, as I will argue, the federal government also has a vital role to play.

The gravity of the problems may lead to political pressures for rapid action—of any kind. My concern is related to our national predilection for "short-term" solutions for problems of any kind.

I am concerned that the growing linkage between our international competitiveness and education might become the only reason for supporting a broad, national effort in education. Our efforts to improve the quality of our educational system should be more broadly based than on this one dimension. While the connection is important, and it is reasonable to argue for increased educational support on such grounds, we must not lose sight of other objectives such as those related to the quality of life—as a nation and as individuals.

BUDGET OVERVIEW OF NSF AND THE DEPARTMENT OF EDUCATION

A review of the total budget numbers for NSF and the Department of Education reveals that:

On what seems to be a definite overall positive note, the NSF shows a proposed increase for a newly defined informal grouping of programs called "education and

development of human resources." Its budget numbers show an increase of \$91 million from \$182 million in FY 1987 to \$273 million in FY 1988.

On the strongly negative side—at least from a budgetary point of view—is what seems to be a virtually total withdrawal of the Department of Education from science and mathematics education. However, almost worse than the withdrawal has been the policy instability exhibited in implementing the Education for Economic Security Act (EESA) of 1984.

It is difficult to understand what anybody hopes to achieve in a program that shoots up to \$100 million in FY 1986, drops to less than \$80 million in FY 1987 and then to zero for FY 1988. Moreover, congressional insistence on a formula approach to grants has led to partitioning the total funding into what often became ineffective small grants of a few hundred dollars. Surely we can do better in terms of stability, priority setting, and long-term commitment to solving serious problems in the areas of science and mathematics education.

THE NSF FIVE-YEAR STRATEGIC PLAN FOR SCIENCE AND ENGINEERING EDUCATION

We have reviewed NSF's "Strategic Plan FY 1987-FY 1991: Enhancing the Quality of Science, Mathematics, and Engineering Education in America," dated February 10, 1987 which was recently submitted to the Congress as required by the Education for Economic Security Act of 1984 (P.L. 99-159). We find that:

It represents important steps in the right direction and seems to draw carefully upon the results of the many studies and reports of recent years concerning science, engineering and mathematics education.

It describes in considerable detail the kinds of activities and programs which will be necessary for our nation to undertake in attacking and solving serious educational problems, and presents them in an NSF context. The listing is rather complete.

It does not, however, provide a clear statement of balance or priorities of science and mathematics education either as part of the total NSF program and budget or among the various parts of the "education and development of human resources." Specifically missing are plans beyond FY 1988, including objectives and general budget targets over the five-year time horizon.

We hope that it will be possible for NSF to extend its analysis and planning in these areas when it eventually receives the strategic studies required by the Congress over two years ago. On this point of strategic planning we do think that NSF has come a long way in the past several years. Director Bloch and the National Science Board are to be commended on this score.

SOME LONG-TERM PERSPECTIVES ON THE CURRENT BUDGETS FOR SCIENCE AND ENGINEERING EDUCATION

It may be useful to review in roughly chronological order several historical perspectives on how we came to our current state of affairs. It is essential to understand that in one form or another we have been debating issues related to science and mathematics education for at least three decades.

Just thirty years ago, in response to Sputnik, we reacted with alarm to what was seen at the time as a crisis of colossal proportions. One of our responses, along with large new investments in space research and technology, was to make large, new investments in science and mathematics education—through NASA, the Department of Defense, and the National Science Foundation. (A landmark piece of legislation was the National Defense Education Act of 1958.)

However, after that initial spurt of funding, interest and enthusiasm for support of science and mathematics education diminished, although during the 1960s education was allocated a sizeable part of the total NSF budget—in the 27-35 percent range—peaking at a level of \$135 million per year in 1968 (See Table 1).

During the 1970s, interest and enthusiasm continued to decline—except in certain congressional circles such as your Subcommittee. You became one of the guardians and guiders of the science education program.

Also, during the mid-1970s science education—particularly certain curriculum development efforts—became embroiled in political controversy as several social science courses were attacked by various political and religious groups. Congress acted imprudently, I think, by terminating support for all curriculum development by the NSF. We are still paying the price in our schools for that turn of events in the form of outmoded and ineffective texts and learning materials.

Another part of the price we paid as a nation for pulling out of curriculum development efforts was that we lost the momentum and value of faculty from research universities being involved in the development of curricula and related materials. I believe it essential that the research community be seriously involved in these ef-

forts. This involvement brings together both researchers and educators in ways that benefit both groups and their work. These interactions also provide ways for linking and grounding research knowledge with practical applications of that knowledge in schools.

As the 1970s drew to a close, investment in science and mathematics education remained in the "backwaters" and the scars from the political battles of the mid-70s still showed. Yet evidence was beginning to mount that all was not well in science and mathematics education. Further, a new dimension was added to growing general concern: problems in engineering education.

With the coming of the 1980s and the Reagan Administration, there was strong opposition to the previous role of the federal government in education. There was a determination to eliminate any federal role in science, mathematics and engineering education at NSF or anywhere else in the federal government. Thus was set into motion the series of decisions which led to the near demise of science education at NSF, except for the graduate fellowships.

Only through the intercession of Congress—Democrats and Republicans alike—was nearly a total elimination of education averted at NSF. But very little in the form of organization or programs survived in 1981 and 1982. Mainly through Congressional prodding and the support of a few Administration officials, the science, mathematics and engineering education areas at NSF have been gradually recovering—far too gradually in the view of many observers, including ourselves.

Some observers and participants point to the fact—noted above—that in earlier crisis years science education accounted for at least 25 percent of the NSF budget. Drawing on that benchmark, and concluding that today's problems are as serious as those in the 1960s, it is argued that the NSF science and engineering education budget should be in the range of \$400 million in the FY 1988 budget as compared with the \$115 million requested. It is also observed by some that reports of the National Science Board and other responsible parties have identified needs for various programs which would likewise add up to about \$400 million at this time for FY 1988.

This chronology clearly shows that science and mathematics education—and more recently engineering education—have a history of "starts and stops," changing focus, and policy instability. As we look at the current situation there is little doubt that we have been in a low investment mode for a long period of time. Major investments over an extended period of time aimed at achieving agreed-upon objectives will be necessary if we are to have any hope of achieving significant progress in solving the array of problems facing us.

A key consideration for Members of the Committee and your colleagues in the Congress is a judgment on how serious is the educational crisis in this country with respect to science, mathematics and engineering education. A question needs to be asked: "Are things as bad as they were in the late 1950s and early 1960s? Or have we made significant progress in spite of the currently documented problems?"

My own view is that we have made progress. Although grave problems exist, things are not as bad as they were in those distant years of the late 1950s. And most surely, we need to avoid the "crisis mode of response" which followed Sputnik. More directly, we do not need crash, catch-up programs aimed mostly at overtaking the Japanese or the Russians or other U.S. competitors.

Of far greater value, I think, would be a policy of sustained and substantial commitment by the federal government in a catalytic role. The focus of this role over the next ten to twenty years could be to make specific advances and improvements along a broad front in cooperation with the states and localities. Perhaps a model—in terms of the long-term commitment but without the large federal financial role—could be the national interstate highway system we committed to during the Eisenhower Administration.

Over thirty years later we are still working at meeting that commitment, but the magnificent achievements have helped transform the country. Such a federal commitment in science, engineering and mathematics education would serve as the catalyst for comparable sustained effort on the part of the states, localities and private sector parties.

SPECIFIC COMMENTS IN THE FY 1988 BUDGET

In reviewing the FY 1988 budget request in the context of the five-year strategic plan discussed earlier, we find ourselves rather puzzled. While we acknowledge the NSF presentation which shows the earlier mentioned increase of \$91 million for "education and development of human resources," we are concerned to see that little increase has been allocated to pre-college education.

While the support for pre-college education appears in the text of the five-year strategic plan and in the public testimony of Director Bloch before your Committee, the proposed budget numbers for pre-college science and mathematics education do not reflect an appropriate level of budgetary commitment. While we are not calling for massive "Sputnik-like" federal action, it is important to acknowledge the vital need for significant responses and investments to cope with the serious deficiencies which have been amply documented time after time in recent years at the pre-college level.

Moreover, aside from the intrinsic need issue, there is the message sent by the "no-growth" action. In an environment of high growth rates throughout much of NSF's budget, there is the inevitable conclusion about the relative lesser importance of pre-college education. The NSF has had enough problems in the past of dealing with the perception that it really did not want to be bothered with this responsibility. Since this does not seem to be the case under the current NSF leadership, we are led to conclude that the "no-growth" decision was a mistake which the agency would cooperate with the Subcommittee in redressing.

The drastic drop-off in pre-college support for science and mathematics education by the Department of Education is one more reason why we must be concerned about the "no-growth" decision for pre-college programs in the NSF's budget request.

It is time to acknowledge firmly and unequivocally that national policy should be to help establish, nurture and encourage the development of a consistent, integrated program of science and mathematics learning from kindergarten through high school. There must be a commitment to persist in our programs at the federal level long enough for change to occur, especially in the areas of curriculum development, teacher training, and the research base in education. Particular emphasis must be placed on the R&D portion of the science education budget.

With respect to curriculum development, we cannot just mail out new curriculum materials to teachers and expect that the materials will be utilized. We know that approach does not work. New training programs must be devised and implemented in cooperation with the states and school districts. Closer attention must be given—using research results—to what works best in teacher training. And given the scarcity of resources, we must avoid methods of teacher training that are not cost effective. More emphasis needs to be placed on an approach to teacher training which is based on continuing education on school premises or in local areas. We need to focus on the design of technologies aimed at upgrading knowledge of content and the methods of teaching it *within* the school and classroom. NSF has an array of capabilities that would be important to such an effort.

While there is no question—nor was there ever one despite what some critics have said in the past—that this leads to federal "control" of education, it does underscore the importance of the federal government in performing educational research and development, investing in curriculum development, and pioneering in new teaching and learning approaches.

The plain facts are that the fifty states and the 16,000 school districts in this country cannot replicate individually all such activities. Yet the implementation of specific programs will rest firmly in the hands of the local schools, their school boards and the states.

At this point I might address a specious argument sometimes used in opposing a federal role in education: since the local school systems involve expenditures of many billions, how can the federal government expect to have any impact with the expenditure of relatively few NSF dollars. Such arguments ignore the fact that the great part of those billions is for teacher and administrative salaries. The amount spent by any given school district on research or course development for science and math education—or any other subject—is tiny or non-existent. This is where the federal effort has high leverage and fills an urgent need in its role as a catalyst.

Further, I would underscore the obvious: pre-college science and mathematics education is where we must begin to insure an adequate flow of informed citizens, candidates for careers in science and engineering, and those who will be in the management and professional ranks of organizations which will depend on advances in science and technology for their well-being and survival.

I want to emphasize that in order for students to enter programs in science and engineering they must have gone through demanding programs in high school. And that for them to have chosen such programs in high school, they must have had the kinds of programs and teachers at the middle school level that provided the right kind of motivation.

Let me now turn to another facet of our "education deficit": those issues surrounding the education of women and minorities in science, mathematics and engi-

neering. These issues have been discussed and debated in terms of equity and fairness for more than a decade. While equity and fairness are still important, it is becoming clear that national need for the talents of women and minorities in science and engineering is becoming the driving force.

As Figure 1 shows, the demographic trends to the year 2000 show a significant dropoff in the numbers of 22-to-30-year olds in the U.S. population. This is the pool from which we obtain our scientists and engineers. Figures 2 and 3 show dramatic reductions in the production of scientists and engineers at all levels if we maintain 1984 participation rates.

There is no doubt that we must tap this pool of candidates if we are to have enough qualified scientists and engineers in the future. We must continue to reach for answers to the under-achievement problems and the under-participation of women and minorities in science and engineering. This means we need on-going research on these issues; we need the development of models and programs which will work. Also, we need more evaluation of various models and dissemination of the results on "what works and why."

Key practical questions include: how can we encourage greater experiences in science and mathematics by young people in these groups? How are we going to get more science and mathematics teachers from the talent pool of women and minorities? NSF has done some exemplary work in the area of women and minority participation but it may be time for a more active, aggressive approach to finding answers to the kinds of questions I have just posed.

To summarize on science, mathematics and engineering education:

We support the NSF budget request and believe it represents a sound move as part of an overall program for improving the state of our economy. Only with respect to the plans and budget request for pre-college education do we differ from the Administration's request. We believe the case is overwhelming for a moderate increase to the range of \$100 million as the beginning of a long-term commitment.

NSF should set a number of specific goals, either alone or in cooperation with the Department of Education (depending on the future role of the Department), in science, mathematics and engineering education. Examples of such goals could be:

- (1) In ten years achieve a significant increase in student performance in mathematics so that we rank closer to the top internationally. Not only would this achievement give us a stronger underpinning for careers in science and engineering but also would permit us to escape the acute embarrassment we should be feeling over our present low preference.

- (2) In ten years achieve a complete overhaul and modernization of mathematics and science curricula in grades K through 12.

- (3) By the year 2000, in close cooperation with the states and school districts, develop and make available appropriate equipment to support effective science teaching in grades K through 12.

- (4) Within five years develop a core of regional "resource centers" for science and mathematics teachers in all parts of the country. Continue to expand such centers in number and capabilities over the next fifteen years.

- (5) Develop the programs that will, within ten years, lead to a doubling of the number of science and mathematics teachers from minority groups.

- (6) Establish and support for the long-term an adequate R&D base in science, mathematics and engineering education.

Such suggestions are only illustrative. We strongly recommend that the pending strategic planning of the NSF be made more explicit in terms of objectives, priorities and proposed budgets. Moreover, unless this strategic outlook is adopted and supported nationally, the prospects for any significant progress in solving the previously outlined problems are not promising. The states and school districts can do and, indeed, are doing much to improve the overall quality of education by increasing teacher salaries, raising standards for teachers and students alike, and by modernizing school organizations and physical plants. Yet, there remain the crucial federal roles as the performer of education research, the catalyst, the networker, and the supporter of the development of new materials and learning methodologies.

INSTRUMENTATION, FACILITIES AND THE HEALTH OF UNIVERSITY RESEARCH

The enormous set of problems associated with inadequate and outmoded equipment and instrumentation has been amply documented in a variety of studies. At this time we will not develop the case further, but do wish to express our support for the NSF position in stressing continued growth as shown in Figure 4.

Another dimension of research in the university setting is the less than desirable conditions in which we find too many of the research facilities at universities

throughout the country. The backlog of needs for new and refurbished facilities is clearly in the billions of dollars range.

Significant measures to deal with equipment, instrumentation and facilities problems are central to improving the state of health of research in universities.

INDIVIDUAL-CENTER RESEARCH AWARDS

Considerable attention and concern has been directed to the issue of an appropriate balance between individual and center (or group) research awards. While I will not include a full analysis of this particular issue in these remarks, the following represents a brief summary of my views:

(1) Several dominant features of the American research system have been credited with its vitality and success: pluralism in support and performance; the universities being the primary locus of basic research; the close and intimate connection between research and higher education; and strong support by the federal government.

(2) It is easy to understand our deep attachment to the concept of the individual researcher working within the intellectual freedom of the university and having access to multiple avenues of support to perform research. We need, however, to remind ourselves that the very pluralism which is the source of our strength also has led to the evolution over the past decades of a number of administrative, funding and research mechanisms. In looking back over the years, it is possible to identify the growth of new and different ways of supporting and performing research: research centers, research institutes, "seed" and "catalytic" programs, research teams, organized research units, interdisciplinary groups—and various combinations of these.

(3) Particularly since the 1960s, research centers and organized research units have been expanding the number. The 1986 edition of *Research Centers Directory* contains 8,354 entries for the 3,000 or so colleges and universities in the United States. Among the trends and developments behind this growth are:

The growing demands on our research system to help cope with what many see as our most important problem: our international economic competitiveness.

The increasing complexity and resource requirements of research in many areas of science and engineering.

The growing interdisciplinarity of research; changing boundaries of traditional disciplines; and the emergence of new "hybrid" disciplines.

A growing perception and understanding that the United States must develop, support and encourage mechanisms for long-term commitment to R&D in U.S. industry.

Closely related to the previous point are the growing interactions between universities and industry in a wide range of research areas in science and engineering.

(4) Taking these kinds of trends into consideration, I support the recent initiatives of the NSF in focusing more attention on the center approach (including the engineering research centers and science centers—with a strong emphasis on industry-university interaction). All of this leads us to the judgment that NSF Director Bloch and the National Science Board are heading in the right direction. Collectively, the various measures represent an exciting concept.

(5) As I consider the balance among the overall components of NSF resource allocations so far during the 1980s, I do not see cause for alarm about the data as reflected in Figure 5. While the percentage allocation for individual investigators has dropped, the overall budget increases have led generally to absolute increases in available resources.

(6) At the same time, however, I wish to reaffirm my own belief and commitment to the need for a strongly supported individual investigator program. This research constitutes the basic building blocks of a strong, healthy, productive science and engineering system. I think I would begin to express concern and alarm if major realignments in future resources resulted in more than modest relative declines in individual project support—in an overall sense and in specific fields. In any event, I would urge continuing to support growth of individual project research at levels at least commensurate with inflation.

(7) One last consideration regarding centers and individual project awards is that individual grants are the best way to assure widely dispersed investigators of the potential for continuing to work. And while I support the use of centers we must be careful about getting to a state of resource allocation and funding mechanisms in which too many investigators would be faced with the choice of congregating in centers or not participating in research of any consequence.

(8) In closing, I'll return to where I began. The questions of balance are vital but they are not likely to have simple answers. It is in pluralism of all kinds—funding,

performers, and research mechanisms—that we find the sources of vitality and success in American science.

Thank you, Mr. Chairman and Members of the Committee, for the opportunity to express our views and for your support of science and engineering over the years.

TABLE 1

Estimated National Science Foundation Science Education Obligations By Function, By Year
(in millions of dollars)*

Fiscal Year	Total NSF dollars	Total SE dollars	Percent SE of Total	Functions*									
				R&D**		Students		Teachers		Institutions		Science and Society	
				%	\$	%	\$	%	\$	%	\$	%	\$
1952	3.47	1.54	44.4	0	0	99.7	1.535	0.3	0.005	0	0	0	0
1953	4.42	1.41	31.9	0	0	98	1.38	2	0.03	0	0	0	0
1954	7.96	1.89	23.7	0	0	95	1.796	5	0.09	0	0	0	0
1955	12.49	2.10	16.8	3	0.06	88	1.85	10	0.21	0	0	0	0
1956	15.99	3.52	22.0	0.4	0.01	67	2.36	32	1.13	0	0	0	0
1957	38.63	14.30	37.0	7	1.00	21	3.00	72	10.30	0	0	0	0
1958	49.97	19.20	38.4	9	1.73	22	4.72	69	13.25	0	0	0	0
1959	132.94	61.29	46.1	14	8.58	24	14.71	62	38.00	0	0	0	0
1960	156.60	63.74	40.7	14	8.92	25	15.94	60	38.24	0	0	0.5	0.32
1961	174.99	63.44	36.3	15	9.52	24	15.23	61	38.70	0	0	0.5	0.32
1962	260.62	83.60	32.1	12	10.03	24	20.01	61	51.00	3	2.51	0.4	0.33
1963	320.75	98.72	30.8	15	14.81	27	26.65	55	54.30	3	2.96	0.4	0.39
1964	354.58	111.23	31.4	15	16.68	30	33.37	51	56.73	4	4.43	0.4	0.44
1965	415.97	120.41	28.9	13	15.65	36	43.35	44	52.98	7	8.43	0.3	0.36
1966	466.43	124.30	26.7	13	16.16	42	52.21	39	48.48	6	7.46	0.1	0.12
1967	465.10	125.82	27.1	17	21.39	38	47.91	38	47.81	6	7.55	0.3	0.36
1968	495.00	134.46	27.2	16	21.51	36	48.11	37	49.75	10	13.45	0.2	0.27
1969	400.00	115.30	28.8	18	20.75	37	42.06	34	39.20	12	13.84	0.2	0.23
1970	440.00	120.18	27.3	15	18.03	38	45.67	37	44.47	9	10.82	0.2	0.24
1971	513.00	98.81	19.3	23	22.73	38	37.15	35	34.58	4	3.95	0.4	0.40
1972	622.00	86.10	13.8	33	28.41	28	24.11	28	24.11	12	10.33	0.8	0.69
1973	645.74	62.23	9.6	34	21.16	34	21.16	21	13.07	11	6.85	1	0.62
1974	645.67	80.71	12.5	36	28.79	22	18.13	25	19.96	14	11.61	3	2.42
1975	693.20	74.03	10.7	35	26.65	26	19.30	24	17.90	13	10.00	2	1.49
1976	724.40	62.50	8.6	17	10.63	36	22.90	6	3.75	37	23.13	4	2.50
1977	791.77	74.30	9.4	15	11.15	31	23.03	11	8.17	38	28.23	5	3.72
1978	864.91	73.96	8.6	12	8.83	29	21.45	14	10.35	38	28.10	7	5.18
1979	928.40	80.00	8.6	14	11.20	28	22.40	13	10.40	36	28.60	8	6.40
1980	996.25	77.19	7.7	18	15.25	25	21.18	14	11.86	34	28.60	9	7.62
1981***	1,041.80	70.70	6.8	—	—	—	—	—	—	—	—	—	—

*The functional categories of obligations are exemplified as follows: Students includes programs such as fellowships and precollege student science training. Faculty includes programs such as teacher institutes and faculty short courses. Institutions includes programs such as RSE (Equipment purchases), LOCI (Local Course Improvement), and CAUSE (Comprehensive Assistance to Undergraduate Education). Science and Society includes programs for improving the public understanding of science and studying the ethical issues in science and technology.

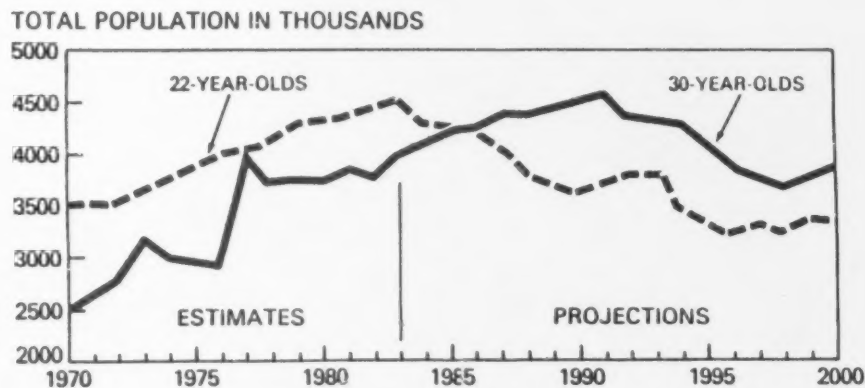
**Until 1977, development projects received most of the R&D funding.

***1981: Breakdown of obligations not available at time of printing.

Source: Directorate for Science Education, National Science Foundation, unpublished data.

FIGURE 1

PROJECTIONS OF 22-YEAR-OLDS AND 30-YEAR-OLDS IN THE U.S. POPULATION

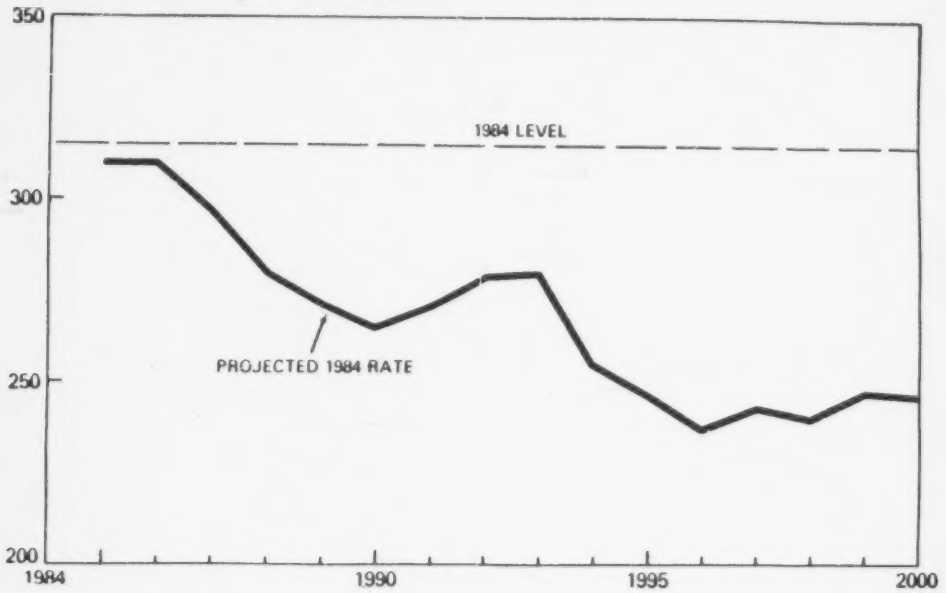


SOURCE: BUREAU OF THE CENSUS.

FIGURE 2

FUTURE S/E BACCALAUREATES, ASSUMING CURRENT PARTICIPATION RATES

S/E DEGREES AWARDED (THOUSANDS)



PHD DEGREES IN NS&E: 1976-2012

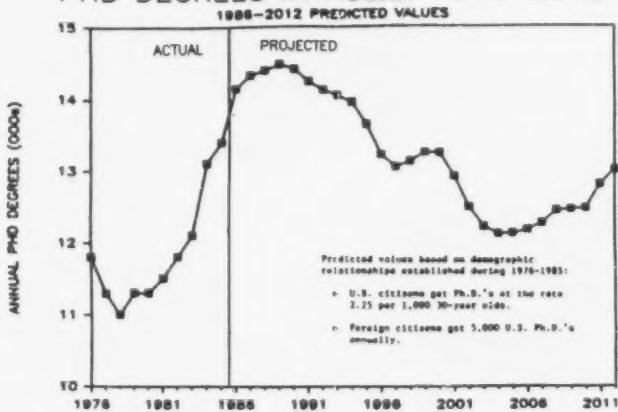


Figure 3

Source: The Science and Engineering Pipeline, NSF, PRA Report 87-2, April 1987, p.16

Note: NS&E Natural Scientists and Engineers

INSTRUMENTATION FY 1983-FY 1987

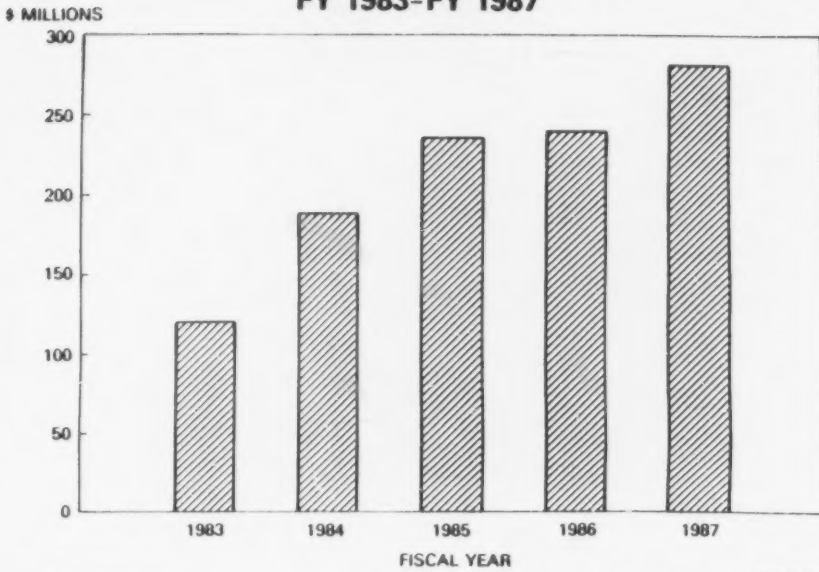


FIGURE 4

NATIONAL SCIENCE FOUNDATION PROJECT BALANCE FY 1983 - FY 1987

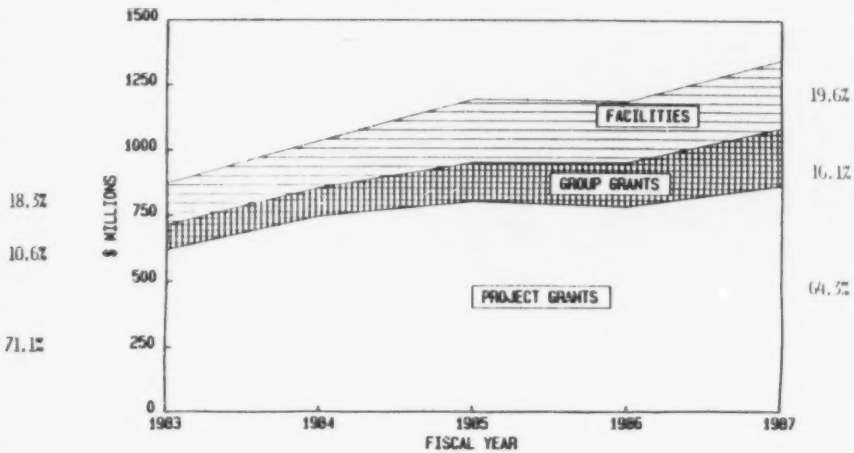


FIGURE 5

* INCLUDES MPS, AAEO, BBS, EMG, & ASC ONLY

Senator KERRY. Thank you very much, Doctor. I appreciate it.

Mr. Weinert?

Mr. WEINERT. Thank you, Mr. Chairman, members of the subcommittee. Good morning.

I am Don Weinert, the Executive Director of the National Society of Professional Engineers. It is a 75,000 member organization, and those members represent all areas of practice, industry, government, education, private practice, construction, and all engineering disciplines. I welcome this opportunity to share in your deliberations about the NSF, the National Science Foundation, and its role in restoring the United States' economic and industrial competitiveness.

Now, understandably my remarks are going to be focused on engineering. However, I want to emphasize that the National Society of Professional Engineers supports the entire National Science Foundation program, including all of the areas of science because both are extremely important. I have a full statement for the record. I just want to emphasize a few points.

First at the outset, let me applaud some of the initiatives of the 100th Congress in addressing our Nation's industrial competitiveness. A few weeks ago I was privileged to testify before Senator Hollings' full Commerce, Science, and Transportation Committee on S. 907, which is the Technology Competitiveness Act of 1987, which you co-sponsor incidentally. And I shared at that time some thoughts on the idea of a national extension service for industrial competitiveness similar to the agricultural extension service.

And it is interesting to note that Representatives Boehlert and MacKay have introduced H.R. 2492 along those same lines, and that initiative, along with S. 907, deserve your careful consideration and support.

Also, Senator Danforth's bill, S. 58, to restore the university R&D tax credit to 25 percent and make it permanent we think is an important initiative, as well as S. 930, Senator Bumpers' bill to create a center on state and local initiatives on productivity, technology and innovation; and finally H.R. 812 and its companion S. 1251, which deal with creating a national quality improvement award similar to the Deming Prize in Japan. We think all of these are important initiatives. We applaud the Congress for those initiatives.

I want to comment on some of the more important aspects of NSF's role as we see it in restoring our Nation's industrial competitiveness. First and foremost, I want to applaud the increasing commitment that we see in the National Science Foundation on engineering research and education under Mr. Bloch's able leadership and Dr. Nam Suh's leadership we see a real increase and commitment to engineering research and education.

We think that those increases are necessary and important when we are dealing with the subject of competitiveness, but I want to emphasize again that we think that those should not be at the expense of the existing programs in support of science, and that these should be increases in addition to the normal increases that we anticipate for the entire NSF program.

We also want to support and comment strongly in support of the whole concept of cooperative research centers. Engineering re-

search centers have already been discussed, and we are strongly in favor of those centers and increased funding for them. But so are the science and technology centers and other cooperative research centers. And they are important for two reasons.

One, to promote cooperation among government, industry and the academia, the universities. And that cooperation is going to be very important to this country if we are going to succeed in this international competitiveness.

And in addition, they support and promote multidisciplinary or interdisciplinary approaches to research. And that also, as Mr. Bloch pointed out, is going to be very important if we are going to succeed in the competitiveness issue. So, we support all research centers.

Third, the grants and the other support for individual research and individual researchers is an investment in human capital. And I think that term was used earlier. And we certainly believe that that investment is warranted. Creating and improving our human capital is in the final analysis the key element in this entire process and, therefore, we must continue our support of individual research as well as the cooperative centers. Both are extremely important.

Fourth, let me mention the instrumentation problem you have already discussed. We have a report that we are just releasing today on this subject from the National Society of Professional Engineers. It is with the record. It points out what everyone knows, that we have a terrible problem, and in the lab facilities and instrumentation area that problem requires immediate attention. In the facilities area you have already discussed it is a problem that could absorb all the resources that we could put to it for the next 20 or 30 years. Suffice it to say that we must give attention in the Federal Government to both problems, the instrumentation and the facilities problem.

Fifth, on the Pre-college pipeline. I would just like to second that comment. We need to do something with math and science at the pre-college level, and we have got to raise the level of competence of our children. We have a national MATHCOUNTS program for seventh and eighth graders, which you may have heard of, that we co-sponsor with the National Council of Teachers of Mathematics and the CNA Insurance Companies. We just had the national finals here, by the way. And you would be interested to know, Mr. Chairman, that Massachusetts placed 11th in the team competition among all 54 jurisdictions represented at that competition.

Senator KERRY. Are you telling me that because they should have been first or because I am proud they are 11th?

Mr. WEINERT. Eleventh is pretty good out of 54 teams competing. And I can tell you the competition is fierce. The Vice President happened to be there and gave the last question. It was quite an exciting moment.

Senator KERRY. Did he know the answer?

Mr. WEINERT. Yes. We provided it.

Sixth, I want to remind you that most engineers, as Mr. Bloch pointed out, are practicing with B.S. degrees. And that in our mind lends great emphasis to the importance of putting more resources into undergraduate education. And I think that was also men-

tioned earlier. And we think more needs to be done than is in the current NSF authorization in that area, particularly the money for experimentation and development of curriculum, new approaches to teaching engineering. We think that is extremely important and needs support from the National Science Foundation.

Finally, however much we applaud these increases, we have got to remember that we are talking about a budget—the total NSF budget that is only 2.5 percent of the non-defense R&D in this country. It is peanuts. The amount for engineering is peanuts. The amount for science is peanuts. We need a much stronger commitment than is even represented by a doubling of the NSF budget over five years.

You asked Mr. Bloch what would he do if he had unlimited funds. It is time for our Nation to make a commitment, in spite of constrained resources. This is an area that is so important that we have got to do more. And so, lest we be too proud of a doubling over five years, we must remember that it is still a pittance compared to what is really necessary.

To close quickly. There is a temptation to direct where things ought to go. And there are lots of ways to solve these problems, and I can understand the Congress' interest in saying, well, it ought to go there. It ought to be distributed there. I applaud, however, your approach and your restraint in allowing the program managers maximum latitude and in taking the systems that we have and improving them and making them better as opposed to trying to usurp those systems. I applaud your restraint in that area.

That concludes my remarks. Thank you.

[The statement follows:]

STATEMENT OF DONALD G. WEINERT, P.E., EXECUTIVE DIRECTOR, NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS

Mr. Chairman and Members of the Committee, good morning. I am Donald G. Weinert, P.E., Executive Director of the National Society of Professional Engineers (NSPE). NSPE is a professional society of over 75,000 engineers representing industry, education, government, private practice and construction.

I. OVERVIEW

I am pleased to join this Committee in its consideration of the programs of the National Science Foundation, as they relate to America's ability to compete in the global marketplace.

The National Science Foundation is a lead Federal agency supporting basic science and engineering research and education, and as such is critical to this nation's economic health and ability to compete internationally.

Before addressing the programs of the National Science Foundation, let me applaud the initiative of this 100th Congress in addressing this nation's technological health. A few weeks ago, I testified before Chairman Hollings and the full Senate Commerce, Science & Transportation Committee on S. 907, the Technology Competitiveness Act of 1987. One of the ideas I shared at that hearing was the concept of an industrial extension service similar in design to the agricultural extension service, and I am pleased to know that Reps. Boehlert and MacKay have now introduced legislation along these lines. The National Society of Professional Engineers supports S. 907 and the Boehlert-MacKay legislation (H.R. 2491), and I urge members of this Subcommittee to support these bills as well.

Other technology-oriented legislation which we believe merits your consideration include S. 58, Senator Danforth's bill to restore the University R&D Tax Credit to 25% and to make it permanent; S. 930/H.R. 2219, Senator Bumpers and Rep. Schneider's bills to establish a Center on State and Local Initiatives on Productivity, Technology, and Innovation; and S. 1251/H.R. 812, introduced in the Senate by Sen. Graham and in the House by Reps. Walgren and Boehlert which would establish a

National Quality Improvement Award similar to the Deming Prize in Japan. Incentives such as the tax credit and the Quality Improvement Award are important in our efforts to reinvigorate America's technology base.

For several years now, America's competitive edge in the international marketplace has been declining. Let's be candid. If we are to restore America's economic competitiveness, we have some hard work ahead of us. It's not an overnight job, but rather a long and arduous process. Much of the difficulty that the United States is experiencing in competing in the international marketplace is a result of U.S. fiscal, tax and trade policies. It is also the result of our under investment in research and education. A focus on the invigoration of our research and education base is an appropriate and necessary element in a multifaceted drive to restore our global economic competitiveness.

The National Society of Professional Engineers believes this revitalization can best occur through the encouragement and strengthening of partnerships between our universities, Federal and state governments and industry. While certainly not the cure-all for this nation's economic health, such partnerships facilitate the transfer of new technology from research laboratories to industry and ultimately to the economy.

The Federal Government's role in these partnerships is an important and vital one. The benefits of an adequately financed technical education system extend to all society. Effective programs require leadership, and the National Science Foundation has demonstrated its ability to launch and guide successful programs. Our ability to expand existing successful programs and to commit to new ones will help insure that America has a strong base of qualified engineering and science professionals. There are many views as to how we should proceed, and some may argue as to which is the best vehicle. However, it is imperative that we move ahead, and the NSF Authorization provides a sound initiative for doing that.

That revitalization of this nation's competitive ability is also dependent on the effective development of our human resources. Certainly, state-of-the-art lab equipment and facilities are important, but it is imperative that we not undervalue and underinvest in the development of our "human capital." The NSF programs in support of research and education involve development of our science and engineering facilities, thus the development of our human capital. The industry-government-university partnerships alluded to earlier are important not only for the research results derived and the transfer of new technologies but for the meeting of minds they allow and inspire. These human partnerships, between academic and industrial researchers, must be supported. They provide a catalyst to the continued growth of this nation's intellectual wealth.

II. THE EXPANDED ROLE OF THE NATIONAL SCIENCE FOUNDATION IN PROMOTING ECONOMIC COMPETITIVENESS

Under Erich Bloch's leadership at NSF, engineering has received greater attention and increased levels of funding, and we are just beginning to see the benefits of the industry-university-government partnerships in effect at the NSF Engineering Research Centers. NSPE is proud to have led the successful lobbying effort two years ago, when Congress added engineering to the basic mission statement of the National Science Foundation.

A. Engineering Research Centers (ERCs)

We feel that the Engineering Research Center Program and as a matter of fact, the other cooperative research centers, constitute one of the most promising of the NSF programs. Of course, the ERC concept has its share of growing pains. Some in industry feel the ERC's are not meeting the specific needs of their particular company. Some in academia feel that the selection process is flawed and too much effort is required to prepare and submit proposals. However, in spite of the growing pains, we feel that the cross-disciplinary interaction provided by the ERCs is long overdue, and is essential if America is to regain her competitive edge. It is too early to expect a flood of specific results from the ERCs, but we are confident that the long-term results will be very positive and beneficial.

These large-scale, multidisciplinary research ventures require increased and long-term support. The ERC program was originated in 1985, with a goal of 25 centers total. By the end of FY'87 there will be sixteen Centers operational, and the FY'88 funding increase would allow for five additional centers. Truly this program has caught the attention and imagination of industry and academia alike.

Competition for the ERCs has been intense. Dr. Nam P. Suh, NSF Assistant Director for Engineering, reported recently that in the first two years of the ERC program, the National Science Foundation received 244 proposals from 114 engineering

schools requesting \$3.5 billion in support. During the same period, NSF had only \$31.7 million to spend on the ERC programs. Benefits of the ERC program extend beyond the actual awards given and occur during the application procedure as well. The process of submitting a proposal requires faculty and industry representatives to join together in planning their proposal. Important contracts are made, establishing the foundation for joint research ventures. Many industry/university partnerships have sprung to life as a result, even without the benefit of NSF funding. Thus the process itself has proven to be a catalyst. We are aware that NSF is working to streamline and clarify the application and selection process and we endorse those efforts to ease one of the more persistent "growing pains" in the ERC program.

Probably the most exciting benefit of industry/academic cooperation is the fact that everyone involved seems to benefit from the experience. When students learn what fuels the industrial process in the "real world" they are better prepared for future careers in those industries. Academic researchers are better able to understand what are industry-relevant areas of investment. And industry benefits by gaining new knowledge, the result of the research. The Centers have helped to build bridges between traditional areas of study, forcing participants to open themselves to a broader spectrum of engineering problems.

I also believe this process will have a synergistic effect in the development of new frontiers of study. The National Science Foundation should encourage ERC candidates to examine the gaps in research and to further consider research into innovative technologies of the future. If these Centers are to assist the U.S. in restoring our competitive edge, we must develop technologies ahead of our competitors, not behind them. These are the immediate results of the ERCs; however, as pointed out earlier, the full potential of the Centers may not be realized for several years. Without sustained Federal support to leverage funds, the ERC programs will be in trouble. Mr. Chairman, these Centers, as well as the Industry/University Cooperative Research Centers, warrant the full increase recommended in the FY'88 proposal (\$18.5 million increase over FY'87, raising the totals commitment to those two programs to \$51.5 million in FY'88).

B. Overall NSF Budget

In this age of budget deficits and restricted government spending, the proposed 16.7% increase in the NSF budget from \$1.623 billion in FY'87 to \$1.893 billion in FY'88 and NSF's plan to double its budget by 1991 exemplifies a commitment to long-term U.S. research and education efforts. We believe our nation's economic future may well depend on our resolve to support this investment in our nation's technology base.

Let me address the proposed FY'88 budgets of the three Directorates within NSF focused on engineering-related activities. The Science and Engineering Education Directorate (SEE) budget would increase by 16%; the Engineering Directorate (ENG) budget would grow by 26% (\$42 million increase); and the Computer and Information Science & Engineering Directorate (CISE) budget would grow by 23% (a \$26-million increase). Together, those three activities represent 32% of the total recommended increase in the NSF budget and demonstrate an on-going commitment to engineering-oriented research and education. In 1983, those three activities accounted for 14.1% of the total NSF budget. In 1988, they would represent 24.5% of the budget. This growth has been accomplished in concert with a moderate pattern of growth in the science directorates, and we applaud this increased attention to engineering-related activities within the NSF.

Focusing briefly on the Engineering Directorate, NSF's Engineering Activity has a FY'88 budget proposal of \$205 million, up from the \$163 million in FY'87. The largest portion of this increase (\$18.5 million) will be in the area of cross-disciplinary research.

This growth curve in funding for these areas may seem dramatic to some, but in comparison with total Federal support for research and education, the increases suggested in the NSF budget proposal represent "seed money." Statistics compiled by the NSF Division of Science Resource Studies indicate that in 1985 the United States spent \$74.6 billion on non-defense R&D, or approximately 1.8% of our Gross National Product (GNP). When you look at the \$84 million increase represented in the three NSF directorates that I mentioned, it amounts to .1% of U.S. non-defense R&D expenditures. When you look at the NSF FY'88 budget proposal as a whole (\$1.893 billion), it still represents only 2.5% of non-defense R&D expenditures in the United States. Also, to keep everything in perspective, I note that the funds for the total NSF engineering budget is roughly equal to the on-campus Federal research and development support at MIT. That means the total NSF commitment to engineering research is about equal to that of the Federal support at only one universi-

ty. We are still far below levels of NSF support needed for the vital task of restoring our nation's industrial competitiveness.

Mr. Chairman, I'm not arguing that the entire burden for civilian research and development in this country should fall on the Federal government. I will, however, suggest that the proposed budget increases recommended for the National Science Foundation provide funding that leverages support from other sources and are warranted and necessary if this Congress is serious in its commitment to strengthening American science and technology.

I am delighted to see the increases that NSF is proposing for research aimed at strengthening engineering education such as the Presidential Young Investigator Awards (PYI) Program (\$5.0 million) the Engineering Initiation Awards (\$2.0 million), and the Creativity Awards for Undergraduates (\$2.0 million). These awards encourage promising young faculty to continue their research careers and remain as faculty and, therefore, help to fill the alarmingly high number of vacancies in engineering faculty positions. Without enough qualified faculty, we jeopardize the quality of our engineering education system. This individual research provides a vital service—focusing on highly specific research questions—and such research must continue. Further, these programs encourage additional funding support from industry and academia. The PYI program, for example, received outside contributions totaling \$8.0 million in FY'86.

C. Instrumentation and Facility Needs

It is well understood that our competitive edge in the international marketplace is based largely on the level of knowledge and skill of our nation's scientists and engineers, a level attained primarily through a rigorous and challenging educational environment. Essential to creating and maintaining such an environment is the availability of up-to-date instrumentation and equipment.

In the area of academic research and development, NSF addresses these instrumentation needs through its individual research awards. Permanent equipment expenditures by the Foundation in the field of engineering, for example, amounted to 10% of the total award budget in FY'86. NSF expenditures for research equipment in all fields in 1987 come close to \$270 million. We want to commend the Foundation for its high level of commitment in this area.

Although NSF is already committed to strengthening its support of instrumentation in undergraduate science and engineering education within the next five years, overall Federal assistance for instructional laboratory and computer equipment remains disappointingly low. I am pleased this morning to add what I feel is a very significant element to the issue of instrumentation and facility needs. NSPE has prepared a new report entitled: *Engineering Education Problems: Laboratory and Computer Equipment*. We are releasing it to the public for the first time this morning. The Report represents a significant investment of resources on the part of NSPE, and should provide a factual basis for the discussion of these needs. The Report is based on information gathered in 1986, and was conducted under the auspices of the Professional Engineers in Education, a Practice Division of NSPE.

The NSPE study reveals that in 1985 Federal funds accounted for less than 5% of the amount spent nationally on instructional lab and computer equipment (roughly \$42,000/school); on average, this percentage has remained unchanged since 1981. In contrast, industrial gifts increased 75% from 1982 to 1985 and now account for half the total value of equipment acquired yearly by the average engineering school (roughly \$466,000/school).

Ironically, a school's good fortune in acquiring new equipment places additional strains on its budget; growing inventories of computer equipment, in particular, demand more maintenance and technical support. Colleges also suffer a critical shortage of both laboratory and computer technicians to operate and maintain equipment and need nearly twice the number they currently employ. Furthermore, with the average expected useful life of computer equipment estimated at just five years, the financial implications of ongoing acquisition and maintenance are impressive.

The value of a student's hands-on experience with state-of-the-art equipment cannot be overestimated. But, with the rapid growth of technology, the price and pace of acquiring engineering laboratory and computer equipment necessary to provide it and even to maintain minimum curriculum standards have increased dramatically in recent years, owing largely to the computer component. The study notes the following: While in 1985, the average engineering college obtained nearly \$1,000,000 in new laboratory and computer equipment combined, the amount spent on laboratory equipment alone actually decreased that same year; in 1981, an average of \$765 per BS graduate was spent on new equipment; by 1985, that value has

spiraled to \$3,016; and in 1984-85, the average value of computer equipment per school was roughly half a million dollars; the average computer maintenance cost annually has now reached over \$130,000/year for hardware and over \$25,000/year for software.

The estimated current value of laboratory and computer equipment per engineering school is just over \$7 million, and the additional amount needed to provide each school with state-of-the-art equipment is estimated at \$6.7 million.

A response to the deteriorating condition and shrinking size of facilities to house instrumentation and equipment is also urgently needed. In the executive summary of a recent conference on the subject, jointly sponsored by the National Science Board, the Office of Science and Technology Policy and the Government-University-Industry Research Roundtable, it was stated that "estimates of the extent of the unmet nationwide need for new construction and renovation [in research facilities at our nation's universities and colleges] vary in the range of \$5 to \$20 billion in the next 10 to 20 years." Among possible solutions to the "brick and mortar" problem may be a reallocation of present funding within the nation's total R&D budget and within its universities and colleges, and passage of legislation authorizing Federal programs for the repair, renovation, or replacement of laboratories and other research facilities at universities and colleges. The University Facilities Revitalization Act of 1987 (H.R. 1905) is an example of such legislation.

III. CONCLUSION

Finally, I believe that as we look to our future, we must look at the pre-college engineering and scientific pipeline. Our children, this nation's future leaders, are not faring well in math and science studies when compared with other nations' students. A series of recent studies at several U.S. universities concluded that U.S. school children from grades one through twelve rank in math skills last among the 20 nations studied. I fear, Mr. Chairman, that we not adequately preparing our pre-college students with the necessary technical skills to live and work in our increasingly complex technical society. The urgency of this problem is highlighted by demographic realities. By the early 1990's the total pool of high school graduates will be 22 percent lower than in 1982. That doesn't give us a very large pool of prospective engineering students! It is imperative that the quality of *all* our high school graduates be raised, especially in math and science, so that a substantial percentage are capable of going on to engineering and science programs in college.

We feel that education of our youth is critical to our future success. We applaud the wide range of Federal programs designed to improve primary and secondary education and to maintain a favorable environment for student loans and scholarship programs. And I urge this Committee, and the National Science Foundation, to explore new means of improving our pre-college math and science education offerings.

NSPE has developed a program which I believe can have a significant impact in this area. It is called MATHCOUNTS, and is a math coaching and competition for seventh and eighth grade students patterned after the "spelling bees." The contest involves over 750,000 students from 7,500 schools in the 50 states, the District of Columbia and Puerto Rico. MATHCOUNTS is a cooperative project of NSPE, the National Council of Teachers of Mathematics, NASA, the CNA Insurance Companies, and the U.S. Department of Education. We were honored at this year's competition to have Vice President George Bush put the final problem to the contestants.

However, even the best prepared high school graduate will require top-flight undergraduate engineering education if we are to be competitive. Remember, most individuals practicing engineering in industry have only a B.S. degree. The value added by that degree must be the best we can offer. The FY'88 NSF budget proposal contains \$5.0 million in new funds for the Engineering Directorate aimed at revitalizing undergraduate engineering curricula. This new initiative in NSF can once again serve as a catalyst for the university community to reexamine its teaching methods and work on new curriculum designs. In a world where technology is moving ahead by leaps and bounds, we desperately need to be preparing our future engineers not only to deal with today's technology questions, but to explore new and perhaps undefined areas. The time has come and gone when an engineer could study a specific facet of engineering and be prepared for a place in the engineering profession. Engineering students must be pushed to excel intellectually across engineering disciplines, and be ready to continue their education throughout their engineering careers. That is why I feel it is important at this time to reevaluate and update our undergraduate curriculum and teaching methods.

Mr. Chairman, before closing, I want to offer one final observation. I know there are many forces pressuring Members of Congress to direct funding to specific elements of the NSF and to specific programs. I want to take this opportunity to compliment you and your colleagues here in the Senate for attempting to provide as much latitude as possible for the program managers. I'm convinced that we will see better results from these programs if we resist the temptation to cross the T's and dot the I's for our program managers.

Mr. Chairman and Members of the Subcommittee, I appreciate this opportunity to come before you to comment on a subject that I consider of great importance. The FY'88 NSF budget proposal offers this nation new and expanding opportunities to improve our research and education base, to bolster our government-university-industry partnerships and, most importantly, to develop our most precious national resource—our people. Well-educated, intellectually challenged people are our "human capital." They are our key to economic competitiveness in the global marketplace, and our hope for a secure and productive future for the United States. It all begins in our elementary and secondary schools and continues with a commitment to supporting research in engineering and science.

The National Science Foundation is well-equipped to take a lead in several important initiatives, and we wholeheartedly endorse the full NSF budget proposal of \$1.893 billion for FY'88.

Thank you for your attention, and for the opportunity to come before you today.

Senator KERRY. Thank you very much, Mr. Weinert. I appreciate that.

Dr. Waugh, I am going to have to go vote but why don't you go ahead and start and we will try and get through.

Dr. WAUGH. Thank you, Mr. Chairman, members of the committee.

My name is David Waugh. I am Dean of Engineering at the University of South Carolina, but I appear before you today on behalf of the Engineering Education Task Force. I appreciate the opportunity to share our views with you on the National Science Foundation budget for the coming year.

The Engineering Education Task Force is a multiple discipline society group working together to address the major issues confronting engineering research and engineering education. The member organizations are the American Society for Engineering Education, including its Engineering Deans Council of which I am Vice Chairman; the National Society of Professional Engineers, NSPE; and the alphabet organization, the National Association of State Universities and Land Grant Colleges, NASULGC. ASEE is a membership society of some 10,000 engineering faculty members, as well as colleges of engineering, engineering technology, and engineering oriented industry. NSPE you have already heard described, some 75,000 professional engineers. NASULGC is a higher education association whose 149 member colleges and universities educate more than 2 million of this Nation's students.

The task force strongly endorses the proposed Fiscal Year 1988 budget for the National Science Foundation. We believe the substantial increases for engineering research and education recognize the vital role of the Nation's engineering enterprise in strengthening U.S. economic competitiveness and the corresponding improvement in the quality of life.

The health of engineering and scientific research, of course begins with the precollege mathematics and science education. There must be enough highly motivated and well-prepared students coming out of the high school pipeline or the Nation will face a continuing and growing serious shortage of the engineering work

force necessary for the increasing needs of government, industry and academia. Pre-college programs at NSF in recent years have helped spur a nationwide effort to improve the pre-college mathematics and science.

While the entire pipeline in education is critical to the Nation's technological future, I will focus remarks on just three areas where NSF can make crucial contributions in engineering education: one, helping alleviate the shortage of engineering faculty; two, revitalizing the engineering curriculum; and three, providing research opportunities in areas of great technological importance.

First, the faculty shortage. Unlike the scientific disciplines where most individuals enter their profession with a doctoral degree, more than two-thirds of this Nation's new engineers enter private industry upon completion of a baccalaureate degree. Because of the high demand for engineers especially in certain specialties, new graduates move directly into industry, commanding good salaries and finding immediate opportunities for professional advancement.

As a result, engineering school enrollments have doubled over the past 10 years. But the number of engineering doctoral degrees awarded has remained about the same, and the percentage of doctoral degrees awarded to U.S. citizens has actually gone down. This relative decline in the production of potential faculty members means the engineering education enterprise is facing a serious faculty shortage. In fact, a 1985 survey showed a vacancy in already existing and funded faculty positions of 8.8 percent, an increase from the earlier studies. This shortage approaches an alarming 20 percent if one seeks to remedy the overload, the gross overload, on today's engineering faculty and to simply restore the more tolerable and favorable student faculty ratios of the mid-1960s. Unless this situation changes, the academic shortage in engineering will grow because of demographic changes and demand for engineers.

Our limited ability to attract U.S. engineering students will continue, much of the vacuum having been filled by foreign nationals. Students from other countries represented an increasing percentage of engineering graduates and, in fact, now receive over half of all engineering Ph.D.s.

Engineering has benefited from international students. They have enriched our programs and have assumed an important role, but we should not rely on them for maintaining the educational and academic research infrastructure. The key is not to restrict international students, but to find ways of attracting more U.S. students to graduate study.

Curriculum revitalization is essential. NSF has maintained strong graduate education programs, and since 1983 has upgraded its pre-college activities. But the undergraduate education, that vital bridge between high school and graduate study or professional career, has been sorely neglected at the Foundation. The new undergraduate initiative will begin to address that unhealthy situation.

Engineering education is buffeted by a host of factors competing for time that influence what students are taught. The rapid change in technology, the use of computers in the classroom, the need to provide students with experience in real world design and manufacturing, the reality of international competition, the need for stu-

dents to acquire greater skills in communication, foreign language, cultures and so on have simply not been something with which we have kept apace. The NSF curriculum program will help develop ways of incorporating design and other things into the curriculum.

Certainly NSF cannot be expected to meet all the needs of engineering education or of competitiveness singlehandedly nor remedy the situation overnight. But Federal leadership is of critical importance. The Foundation can leverage resources.

And lastly on the research, the full spectrum of research opportunities is essential. The Presidential Young Investigators, the Research Initiation Awards, the traditional individual investigator, and a special word for the engineering research centers. Perhaps too soon to evaluate their total effect, but their impact on many technologies of bringing together of industry and academia that leveraging resources with the states and the universities is of critical importance to this country.

Mr. Chairman, I appreciate the opportunity to speak on behalf of the Engineering Task Force.

[The statement follows:]

STATEMENT OF DR. J. DAVID WAUGH, DEAN, COLLEGE OF ENGINEERING, UNIVERSITY OF SOUTH CAROLINA

Mr. Chairman and members of the committee, on behalf of the Engineering Education Task Force, I appreciate this opportunity to share our views on the National Science Foundation budget for Fiscal Year 1988. The Engineering Education Task Force is a multi-society group working together to address major issues in engineering research and education. Member organizations are the American Society for Engineering Education (ASEE), including its Engineering Deans Council, the National Society of Professional Engineers (NSPE) and the National Association of State Universities and Land Grant Colleges (NASULGC).

ASEE is a membership society of more than 10,000 faculty and students, as well as schools of engineering, engineering technology, and engineering-oriented industries. NSPE is a professional society representing over 75,000 professional engineers in private practice, industry, government, construction and education. NASULGC is a higher education association whose 149 member colleges and universities educate more than two million of the nation's students.

The Engineering Education Task Force strongly endorses the proposed FY 1988 budget for the National Science Foundation (NSF). We believe the substantial increases proposed for engineering research and education recognize the vital role of the nation's engineering enterprise in strengthening U.S. economic competitiveness and improving the quality of life.

The health of engineering and scientific research and education begins with precollege mathematics and science education. Enough highly motivated, well-prepared students must come out of the high school pipeline or the nation will face a serious shortage of the engineering workforce necessary for the increasing needs of government, industry and academe. Precollege programs at NSF in recent years have helped spur a nationwide effort to improve precollege mathematics and science.

While the entire educational pipeline is critical to the nation's technological future, I would like to focus my remarks today on three areas where NSF programs can make crucial contributions in engineering education: helping alleviate the shortage of engineering faculty, revitalizing the engineering curriculum, and providing research opportunities in areas of great technological importance.

THE FACULTY SHORTAGE

Unlike the scientific disciplines where most individuals enter their professions with a doctoral degree, more than two-thirds of the nation's new engineers enter private industry upon completion of their baccalaureate degrees. Because of the high demand for engineers, particularly in certain specialties, new graduates can move directly into industry, commanding good salaries and finding immediate opportunities for professional advancement.

As a result, engineering school enrollments have doubled over the past 10 years. But in the same period of time, the number of engineering doctoral degrees awarded has remained about the same and the percentage of doctoral degrees awarded to U.S. citizens has gone down. This relative decline in the production of potential faculty means that engineering education is facing a serious faculty shortage. In fact, a 1985 survey by ASEE showed a vacancy in already-existing and funded faculty positions of 8.8 percent, an increase from earlier studies. The shortage approaches an alarming 20 percent if one seeks to remedy the overload on today's faculty and restore the favorable student/faculty ratios of the mid-1960's. Unless this situation changes, the academic shortage in engineering will grow into the late 1990's because of demographic changes and increased government and industry demand for engineers.

With our limited ability to attract U.S. engineering students to continue in full-time graduate school and faculty careers, much of the vacuum in graduate programs has been filled by foreign nationals. Students from other countries represent an increasing percentage of engineering graduate students and, in fact, now receive more than half of all engineering PhDs awarded each year.

While international students have enriched our engineering programs and have assumed an important role in U.S. engineering schools, we should not rely on them for maintaining the educational and academic research infrastructure. The key is not to restrict international students, but to find ways of attracting more U.S. students to academic careers.

This is a complex problem, but NSF can help by providing incentive programs which enable students to pursue graduate study without undue financial hardship. Thus, we fully support NSF's plan to fund an additional 200 graduate fellowships in FY 1988. We also feel that the stipends need to be high enough to attract the top engineering school graduates. Equally important is the opportunity for graduate students and engineering faculty to participate in exciting research. A major advantage of academic over industrial research is the greater freedom of inquiry in an environment which encourages creativity. For that reason, we welcome NSF's proposal to expand the Engineering Initiation awards (which provide first-time research funding for new faculty), as well as the overall number of engineering research grants. Of additional assistance is the Foundation's plan to fund 85 new Presidential Young Investigator (PYI) awards in engineering in FY 1988. This program offers young PhDs substantial five-year research support in collaboration with industry, and serves as a valuable incentive for creative academic research and a means of professional recognition.

NSF can also minimize the faculty shortage through its proposed faculty development programs in the research directorates and in the education directorate. Existing faculty will be able to develop model plans for updating their technical and teaching skills, as well as experiment with interactive computer simulations and video programming for making teaching more efficient and effective. Along with experimental opportunities in teaching and learning, NSF programs could support expanded workshops, seminars, and faculty networking.

An example of what can be done in faculty development is the continuing education program that has been developed by ASEE and the Massachusetts Institute of Technology, with partial funding from the Foundation. This summer, more than 100 engineering faculty will take part in two-week, concentrated courses offered at various locations around the country. These courses are designed to update faculty in specialties outside of but related to their own areas of expertise.

CURRICULUM REVITALIZATION

Because engineering education is focused at the undergraduate level, the undergraduate education initiative at NSF is of special importance to the field. Over the past several years, NSF has maintained strong graduate education programs and since 1983, has considerably upgraded its precollege activities. But since the 1970's, undergraduate education—that vital bridge between high school and graduate study or professional career—has been sorely neglected at the Foundation. This new undergraduate initiative will begin to redress that unhealthy situation.

One of the most important elements of the initiative is the program for revitalizing the engineering curriculum. Engineering education today is buffeted by a host of factors that influence what students are taught: from the rapid pace of technological change and the use of computers in the classroom, to the need to provide engineering students with greater experience in real-world design and manufacturing processes. Moreover, in the new reality of international competition in technology, students need to acquire greater skills in communications and knowledge of foreign languages and cultures.

The engineering curriculum, in general, has not been able to keep pace with these demands. Under the new NSF curriculum program in the engineering directorate, faculty will be able to develop ways of incorporating design, synthesis and computer integration into the curriculum, as well as finding means of using computers and video programming to improve teaching. This can include development of new computer software, self-paced learning modules or new instructional technologies for face-to-face or learning at a distance. Other areas of experimentation can focus on interdisciplinary efforts for ensuring engineers understand the political, social and economic contexts in which engineering is practiced today.

Certainly NSF is not expected to meet all of the needs of engineering education and competitiveness singlehandedly, nor to remedy the situation overnight. But by demonstrating federal leadership in these areas of national importance, it will enlist the best minds in academia in researching and developing solutions to these challenges. The Foundation can also leverage its resources with industry, state and local governments and academic institutions in a broad-based, synergistic effort to address the competitive challenge of further developing human resources.

THE CONTRIBUTION OF ENGINEERING RESEARCH CENTERS

Another key NSF activity in strengthening our nation's ability to compete is the Engineering Research Centers (ERC) program. While it is yet too early to gauge all of the benefits that will come from the multidisciplinary centers, they have already prompted significant intellectual and financial cooperation among the academic community, state governments and industry. Many exciting projects are being developed at the ERCs which have the potential for major breakthroughs in such areas as robotics, biotechnology, composite materials, and automated manufacturing.

But the ERCs also have important benefits for the human resources side of the equation. Through the centers, faculty, graduate students and undergraduates have the opportunity to work with industry researchers on cutting-edge technological challenges. This gives them direct experience with industry methods and industry needs, and fosters the people-to-people connections that are the basis of technology transfer. The ERCs also enable many more academic researchers to take advantage of state-of-the-art equipment and facilities.

CONCLUSION

While the problems of enhancing the nation's economic competitiveness are complex, we believe that the National Science Foundation can help find the answers.

We strongly support the FY 1988 budget proposal for NSF and praise the Foundation's commitment to building and sustaining a high level of federal support for engineering and scientific research and education. The 17 percent increase for FY 1988 represents an important step toward the most desirable goals of doubling the Foundation's budget over the next five years.

It is our hope that the Committee will view this budget as an important investment in the nation's technological and economic future, the rewards of which the nation will reap many times over. Thank you for this opportunity to appear before you today.

Senator KERRY. I thank you very much, Dr. Waugh. I am sorry you felt some pressure beyond the normal pressure that we feel.

If you will excuse me again, I will go and vote. I will get back just as fast as I can, and then we will follow up. We will stand in recess till then.

[Recess.]

Senator KERRY. The hearing is reconvened again. I really apologize about that. I think you are all veterans of it or at least some of you are veterans. But everybody up here acknowledges we all serve on too many committees and are trying to be in too many places at the same time. Like the weather, we complain and nothing happens or nobody can do anything about it.

A number of my colleagues for better or worse—this committee is also very well represented on the Finance Committee, and the Finance Committee today is embroiled in the markup of catastrophic health insurance, so there is a tremendous conflict. That is

where Senator Rockefeller had to go, and others have not been able to come.

But the important thing is obviously that all of your testimonies will be placed in full in the record, and we will have a chance to explore further some areas shortly.

Dr. Moore, thank you for your patience.

Dr. MOORE. Thank you. I am Berrien Moore, the director of the Institute for the Study of Earth, Oceans, and Space at the University of New Hampshire. My testimony, however, is based upon concerns which I have that go far beyond the consequences of my directorship. I am a past member of the Committee of Earth Sciences of the Space Science Board. I am a member of the Space and Earth Sciences Advisory Council to NASA, and I have recently been appointed to the National Research Council Committee on Global Change. As a consequence, I am close to many of the issues being discussed here today, but I want to emphasize that I am speaking from my own point of view rather than as a spokesman for any of these groups.

I would like to address an important aspect of the NSF budget where I believe I have qualification. This is the request for the support of the Global Geosciences Initiative.

Global Geosciences is an extraordinary new initiative to study the earth as an integrated system. It is an exciting approach and it builds upon a strong disciplinary base. The scientific issues that it considers are important unto themselves, but also they are important to the well-being of society. And I would like to break for a moment from a formal testimony and describe the scientific context that we face and the scientific issues posed in a changing planet.

It is now common knowledge that the greenhouse gases, CO₂ and methane for instance, are increasing in the atmosphere. There are unexplained variations in ozone particularly over Antarctica. In the industrialized world, for instance in New England, there is a rapid decline of forests, particularly the red spruce. In tropical regions our best estimates are between 70,000 and 100,000 square kilometers are lost each year due to deforestation.

In order to put that in context, Senator, the combined area of Massachusetts, Vermont and New Hampshire is 70,000 square kilometers. So, each year we are losing tropical forests that constitute that same area. And that is the lower estimate.

We are uncertain about the effects of deforestation. We know that, of course, there are species lost and that the gene pool is degraded. However, we believe that there are probably impacts upon the CO₂ cycle and certainly climate itself.

Continuing the train of thought associated with carbon dioxide because it is such a perfect metaphor for global change, we think that between 2 and 3 billion metric tons of CO₂ go into the ocean each year, which is about half of fossil fuel load. We are not very confident about this estimate, and we are far, far less confident about what the ocean's response might be in a changing climate.

These human-induced changes in the planet not only increase the practical importance of the science that seeks to understand the changes, but interestingly, the changes themselves afford perhaps a means towards gaining this understanding. The forcing of

this planet, the forcing of the Earth system, is in the words of Roger Revelle a planetary experiment at the global level. Consequently if the right questions are asked and the appropriate data are taken in a timely fashion, then this global experiment holds the promise for providing new insights into the life support processes of the planet.

I believe that the Global Geosciences Initiative offers the realistic possibility of gaining this significant insight. The Fiscal Year 1988 budget builds on the NSF Global Geosciences program begun in Fiscal Year 1987, and the Fiscal Year 1988 increase of \$24.6 million I believe to be appropriate.

There are nine components to the program, and rather than go through each one, let me just try to give a flavor for the various components.

There is the Global Tropospheric Chemistry Program which is trying to understand the chemistry per se of the troposphere. The troposphere is essentially the lower part of the atmosphere, the one in which we live. But it goes beyond that. It is trying to look at the interactions between the troposphere and the biosphere. We now know that there are significant sources of trace gases from the biosphere. The reason the Smokey Mountains are called Smokey Mountains is because of the hydrocarbons that are coming from the trees.

We also find this same kind of coupling of atmosphere and the surface in the TOGA program, which is the Tropical Ocean/Global Atmosphere program, which is trying to understand the patterns that set up the El Nino events that we believe have their origins in the South Pacific, but they may well also connect all the way over to the droughts over Africa and monsoons in India.

We find the same kind of coupling when we think of linking the Tropical Oceans program with the World Ocean Circulation Experiment, the Global Ocean Flux Study, which is trying to understand the biological production and decomposition in the water column, and the Ocean Ridge Crest program. We begin finally to get a complete view of the oceans as a whole. And this complete view is essential if we hope to understand such things as the carbon dioxide problem because as I began earlier, much of the excess buildup in CO_2 has its ultimate home in the oceans. The question is at what rate, and what would be the oceanic response in a changing climate.

Three other areas. We have, for instance, the Global Ecosystem Dynamics, which is trying to understand the characteristics of ecosystems globally and particularly in a changing climate.

There are two other aspects that I think are particularly interesting and important. One is the Paleoclimates from Ice Sheets. At this moment a colleague of mine is in Greenland, and he with others are trying to begin to select the site where we might take a core and thereby reconstruct the last 100,000 years of climate. This is extremely important as we try to understand what a changing climate can mean.

For instance, we have already used this approach in the past when we wanted to reconstruct what was the pre-industrial CO_2 concentration in the atmosphere. You could not use any of the data that had been collected at the time. I spent about half my time in

Paris and in Stockholm, and some of the best records that were taken in Paris. But the records were taken in Paris, with all of the coal burning, so the records were essentially unusable in terms of reconstructing that pre-industrial period.

The Swiss were able to take a core, go back to the layer of ice that was essentially deposited at the time of, say, 1850 and reconstruct from that core what the CO₂ concentration of the atmosphere was at that time. We now know then there has been an increase of about 28 percent in CO₂ concentration.

The Paleoclimates program would like to do the same thing over a much longer period and try to reconstruct the climates.

And finally, there is a Solid Earth program. We are essentially trying to look into the earth, itself, and understand how the earth as a physical-chemical system works.

To conclude, I believe not only do the constituent research components in the geosciences initiative need to be supported, but I think the initiative itself is essential. There is today in the United States a convergence and a unity within earth science. This convergence at the Federal level, particularly the vital cooperation—and I might say the vital new cooperation between NASA, the National Science Foundation and NOAA—is highlighted in a recent report of the Earth Systems Science Committee of the NASA Advisory Council.

Furthermore, this report endorses the Global Geosciences Initiative as the central feature in a multi-agency, multidisciplinary study of the earth.

I should note that the report itself was endorsed in June of 1986 by the heads of NASA and NOAA and the National Science Foundation.

And finally, this convergence—this unity in the earth sciences is beginning to be expressed at the international level. In September of 1986 the General Assembly of the International Council of Scientific Unions unanimously endorsed the program entitled the International Geosphere-Biosphere Program: A Study of Global Change. This widespread scientific support for a new look at the earth is not based upon the propositions of a few, but rather it is the result of a heightened common awareness that scientific issues now confront us that demand a more integrated methodology.

The scientific disciplines provide the foundation, but upon this foundation an expanded and new structure must be built. This new structure must focus on the linkages between scientific disciplines and the processes that affect and control our dynamic but delicate planning.

Thank you.

Senator KERRY. Thank you, Dr. Moore. I appreciate that important endorsement of the effort.

Dr. Rosenzweig?

Dr. ROSENZWEIG. Thank you, Mr. Chairman.

Mr. Chairman, I am here as President of the Association of American Universities and also on behalf of the Council of Graduate Schools and the National Association of State Universities and Land Grant Colleges.

We appreciate the opportunity to make some comments on the authorization for the fiscal year 1988 National Science Foundation

budget, a budget which I should say at the outset we strongly support. The 17 percent increase over fiscal year 1987 is a gratifying indication of commitment to science and technology, and that is supported further by the goal that the administration has set of doubling the fiscal year 1987 size of the Foundation within five years.

That that commitment has been made is certainly a tribute to the advocacy and skill of Erich Bloch, who testified here earlier this morning. It is one of the great political feats of ledger domain in the last few years in Washington that he could persuade this administration to commit itself to a doubling of the size of that agency. And we commend him for it.

Let me make a couple of observations about some of the issues that the NSF budget raises. Having said that we support strongly the proposed doubling of that budget, as well as the fiscal year 1988 component of that doubling, it is also necessary to say that we recognize that no amount of money will be seen by all of the potential claimants for it as enough. It is always possible to make a case for spending more on this and less on that within the context of any budget. Moreover, Congress has the right to do that, and if the reasons are compelling for making changes of that kind, I suppose it even has the duty to make those changes.

I would urge you, though, to resist the temptation to fiddle with the internal allocations in this budget and to resist the efforts of others to do so. It is not that it is a perfect budget by any means. There is no such thing I suppose. It is that the shape of the budget as it has been brought to you is the product of deliberations within the Foundation in which the needs of science and technology have been primary. It is not perfect, and it certainly is not to everyone's satisfaction, but it is likely to be better than any other result that will be produced by ad hoc tinkering with the numbers here and there.

Second, I would like to express our support for the increased emphasis on centers, both engineering and multidisciplinary science centers, as a way of organizing the research effort so as to promote areas of research that are harder to stimulate in the regular departmental structure of a university.

Those centers are not, however, as Mr. Bloch said, a substitute for the basic engine of creative science which has been in this country the investigator-initiated project.

Here I want to offer the committee a caution. It seems to me that if we are not careful, we may go so far in our enthusiasm for what I would call programmatic science that we can risk discouraging the scientist whose work does not lend itself to that form of organization. In its planning so far for the centers program, the Foundation has been reassuringly sensitive to this concern. But as science comes increasingly to be seen as important to one national goal or another, the pressure will be to organize it in pursuit of those goals. We see that in much DOD research already and increasingly in the new enthusiasm for high technology.

Well, all of that is fine, but it is important to remember that it all rests on a base of research that was undertaken for no reason other than it seemed to someone interesting given the state of knowledge as it existed at the time, and that someone else was

willing to pay for it. In the last generation and a half that someone else typically has been the National Science Foundation in the area of the physical sciences and mathematics, and that role for the Foundation is an essential underpinning of everything else that the Foundation proposes to do of a more programmatic and directed nature.

Finally, Mr. Chairman, I want simply to underscore the remarks that have been made by several others here this morning about the serious and pervasive need for renovation and construction of research facilities.

The Federal Government has not been in that business for nearly 20 years. As a consequence, universities have undertaken to find money for buildings either through state appropriations which have waxed and waned as the economic prospects of states have, through borrowing money, through raising money. Those are all limited strategies. In the end they will not together be successful without the renewed participation of the government. I think the program of roughly \$250 million a year, matching, which would be a half billion dollars a year over 10 years, would be a good start toward that goal.

Thank you, Mr. Chairman.

[The statement follows:]

STATEMENT OF DR. ROBERT M. ROSENZWEIG, PRESIDENT, ASSOCIATION OF AMERICAN UNIVERSITIES

Mr. Chairman, Members of the Committee: I appreciate the opportunity to discuss with you the proposed budget of the National Science Foundation. It is, in all important respects, an excellent budget. The NSF request affirms the importance of academic science and engineering and quality education to the nation. It recognizes one inescapable fact: even in these difficult times we must invest adequately in new knowledge and people, our nation's two most valuable resources.

In its totality the NSF budget shows good balance between individual investigator-initiated research, new investment in interdisciplinary research centers and investment in human resources. The FY 1988 proposals and the commitment to double investment in NSF by FY 1992 acknowledge the leadership and dedication of this Subcommittee and the Congress as well as that of the Director of the National Science Foundation, Mr. Erich Bloch. This dedication not only helps assure the future strength of U.S. science, but plays an important role in ensuring that our country can meet the challenge of leadership in the next decades. Mr. Bloch has brought vigorous public leadership to the Foundation. I should like to take this opportunity to commend him publicly for a job well done.

We are, of course, especially gratified by the strong affirmation of the priority given to NSF by the FY 1988 budget request and the policy goal of doubling the Foundation's budget by 1992. My testimony focuses on two particular aspects of the National Sciences Foundation's program—(1) the appropriate role of research centers as a strategy or vehicle for meeting directly the needs of U.S. science and indirectly the broader economic and social needs of our society, and (2) the Foundation's proposed investment in science and engineering education programs. To these I should like to add a third issue—the NSF role in addressing the research facilities deficit of our universities.

Research Centers and Groups

The issue of the appropriate role of interdisciplinary science and technology centers is currently being considered in relation to the more traditional vehicle of federal support for basic research—the individual investigator grant. Recently Dr. Harold Shapiro, President of the University of Michigan, addressed this matter on behalf of the AAU before the House Subcommittee on Science, Research and Technology. I will summarize his principal conclusions and concerns; I believe they merit careful consideration.

1. *Increasing the share of the NSF budget devoted to the support of interdisciplinary and/or multidisciplinary research center is—at the current time—an appropriate strategy to pursue.*

Many useful discoveries in contemporary science are available only through an interdisciplinary approach that would be difficult for an individual investigator to manage. Many fields now require the merging of ideas, results and techniques from separate disciplinary areas in order to fully exploit our scientific potential. Evidence to support this view is already visible in many fields and in these areas NSF efforts can be supportive and helpful rather than distorting and frustrating to both scientist and patron.

The call for interdisciplinary and/or multidisciplinary research is as old as the formation of the scientific disciplines themselves. Specialization has had overwhelming benefits, but it also produced a new need to transcend these boundaries. The current NSF initiative, supported by similar efforts currently in place in many educational and research institutions, is, therefore, part of a long history of concern with respect to this matter.

2. *The rate of expansion of NSF funding for research centers should be cautious, retain its flexibility, and be the subject of ongoing evaluation.*

In developing new centers, NSF faces several challenges. Our scientific resources (human and physical capital) must be used in the most effective way. Strong team leaders with both vision and disciplinary credibility must be located. NSF must do well the difficult job of providing for sound project management. The Foundation must provide leadership in fashioning a congruence of vision between it and prospective scientific leaders. Selecting areas which can be effectively exploited by research center efforts, and forecasting future scientific developments pose difficult challenges.

For these reasons, we believe that NSF's initiative to expand in relative importance the funding of research centers should be constrained by the following considerations:

(a) *The performance of each center should be evaluated at stated intervals over its lifetime. Support for them should be time-limited.*

Organizations—as opposed to individuals—develop a bureaucratic capacity to sustain their support beyond their useful “lifetime.” Greater discipline is required, therefore, in terminating support at the appropriate moment. It would be extremely unfortunate if the Foundation gave up too much of its future flexibility by finding itself permanently “engaged” to a fixed group of centers. We especially need to avoid the trap of assuming that multidisciplinary efforts cannot be evaluated by experts in the component disciplines. We are pleased to learn, therefore, that the Foundation has enlisted the assistance of the National Academy of Sciences in developing its plans for developing the centers. The Academy's report, expected in June, will be widely read by faculty and administrators alike.

(b) In many fields, this form of organizing research efforts would not be appropriate (i.e., most effective). Careful thought needs to be given to selecting those areas of science which could be best assisted by this form of support. Further, in areas where such research centers would be effective the optimal forms (e.g., extent of industry participation) will vary a great deal. Experimentation with different multidisciplinary approaches should be encouraged.

(c) There is a need to ensure that these research centers play an appropriate role in the education of the next generation of scientists and researchers.

The contemporary American research university is characterized by an unusually fruitful and highly admired joining of the conduct of research and the education and training of new scientists and researchers. It is essential, therefore, that these new research center initiatives indicate and subsequently demonstrate how they will meet their educational responsibilities. We need more focus on the potential synergy of such centers with both undergraduate and graduate education. We talk often of leveraging public research funds by also attracting private funds to such projects, but we often overlook the most important leverage available through the public support of research—the ability to use that support to enhance science and engineering education at undergraduate, graduate and post-graduate levels. More broadly speaking, research centers that do not support the mission and values of the institution within which they operate will not prosper. It is important, therefore, to structure these centers so that faculty loyalties to the university as a coherent inter-related academic community are reinforced rather than undermined. Finally, we commend the Foundation for sustaining the individual investigator-initiated research grant as the dominant means of funding academic science and engineering. Of the total \$1.5 billion requested for research activities the core research programs account for more than two-thirds. We vigorously support the Foundation's commit-

ment to providing for expanded investment in its core programs. It would be shortsighted and, I believe, a mistake of major proportions if we were to proceed with the proposed development of new interdisciplinary centers and groups at the expense of our continuing commitment to individual investigator-initiated research. The two forms complement one another. In contemporary academic research each has become essential to our future leadership in science and technology.

To summarize, we support the Foundation's initiatives to foster interdisciplinary science and engineering centers. While the challenges are significant, so also are the needs and opportunities before us. The universities and their national associations stand ready to support and, as appropriate, assist the Foundation and the Congress in developing the new center and group activities.

Science and Engineering Education

Turning to my second topic, I must acknowledge the importance of the Foundation's science and engineering education programs to our entire educational system. The vitality of our research system depends on the strength of our educational enterprise, from the precollege K-12 level and two- and four-year undergraduate programs to graduate and post-doctoral programs. In each of these areas, NSF has a unique leadership role to play. While responsibility for education is shared at the local, state and federal levels, the need for national leadership in stimulating new approaches to quality education in science, mathematics and technology at all levels of the system is greatly recognized. We fully support, therefore, the Foundation's efforts in strengthening each of its science and engineering education activities.

The Precollege Level

Perhaps no area is more fundamentally important to the future health of our educational system than our elementary and secondary schools. I applaud NSF's efforts to provide leadership in strengthening our schools and our teacher preparation programs through its K-12 precollege activities. I can assure this Committee and the Foundation that the executive heads of the 54 AAU universities are keenly aware of the needs at the precollege level. We enthusiastically support NSF's leadership and creativity in this area. Its commitments to strengthening teacher preparation, improving the use of instructional technology and upgrading schools curricula in science and mathematics are vital national efforts.

The Undergraduate Level

At the undergraduate level the Foundation has created new opportunities for research institutions to engage students in sponsored research programs. We support the Foundation's effort to foster, within its research programs, a closer coupling of undergraduate instruction with research. We also recognize the serious needs of undergraduate institutions for NSF support to improve instructional equipment and curricula, especially in rapidly moving fields, such as engineering. Because universities confer a majority of undergraduate degrees awarded each year, we are keenly aware of the pressing need to modernize undergraduate instructional programs in science and engineering. The experience of the first two years of operation of the NSF College Science Instrumentation Program illustrates the needs. In two years the program received more than 2200 proposals; yet only 400 awards could be made. The needs far surpass the available resources. We are pleased to know, therefore, that the budget provides for 350 additional equipment awards next year. In our view NSF should continue to address undergraduate needs and opportunities through its research activities as well as through specially designed competitive grant programs, such as the College Science Instrumentation Program.

The Graduate Level

At the graduate level, the Foundation proposes to add 200 new graduate fellowships per year, and to provide for needed adjustments in the stipend. This is heartily endorsed by the university community. It will, I believe, pay great dividends. I must point out, however, that once again no adjustment is proposed for the cost-of-education allowance which accompanies each fellowship. While the stipend, now \$12,300, has been increased to keep pace with the rising cost of living, the education allowance, which is intended to cover the cost of tuition at institutions selected by NSF fellows remains unchanged at \$6,000, well below required levels.

Greater numbers of U.S. citizens, especially minorities and women, must be attracted into doctoral programs in science and engineering. Recent studies suggest that we may now be losing ground in the effort to decrease our dependence on foreign national scientists and engineers. For example, more than half of our new engineering PhD's are now awarded to foreign nationals. A significant and rising proportion of new mathematicians and physicists also are foreign nationals. All of

these are disciplines essential to any modern technological society intent on maintaining its competitive posture in the marketplace. The marketplace is providing insufficient incentives to talented undergraduates; national leadership and stronger incentives are needed. Therefore the further strengthening of the NSF Graduate Fellowship program, as well as the planned continuation of Presidential Young Investigator program, are essential and welcome investments.

Research Facilities and Equipment

I turn now to my third topic: the research facilities deficit of our universities. In recent years the Foundation has made significant progress toward addressing one crucial aspect of the research facilities capital deficit in our universities. The Foundation has recognized and accepted partial responsibility for addressing the need for modern research equipment in university laboratories. Only a few years ago the Foundation allocated about five percent of its research funds to equipment. Today NSF is spending between 18 and 20 percent of its research funds, or more than \$250 million, on research equipment. In addition it has provided effective leadership in articulating the problem and mobilizing the research agencies, industry and others in response to it. We congratulate NSF for this leadership and applaud the progress which has been made. The Foundation and other federal research agencies must help to ensure that investigators funded to carry out NSF research programs have the tools required by effective competitors in the international scientific arena.

However, research equipment is only a part, and the smaller part, of the research facilities problem. Inadequate laboratory buildings constitute the greater problem. And NSF lacks an equal commitment to the modernization of research laboratories.

During the past twenty years federal investment in university research buildings has declined by 95 percent in real terms. In other words, Federal investment in the construction and modernization of university research laboratories has declined twenty-fold. A technologically healthy economy not only requires us to attract, train and hold sufficient numbers of our most able people in science and engineering careers, it requires that we make the necessary investments in research facilities and equipment. Simply put, universities have a very serious problem of obsolescence. While we still can rightly claim to have the most highly developed university system in the world, we must begin to acknowledge that for more than twenty years we have failed to make the appropriate federal investments in university research facilities. As a result, despite the considerable investments made by the states and by the institutions themselves, many of the research facilities which house national research programs are now out of date; they have become inhospitable and inefficient homes for modern science.

The research facilities problem has been widely documented and acknowledged. The 1986 report by the White House Science Council Panel on the Health of U.S. Colleges and Universities, for example, concluded that a major catch-up effort is needed. It recommended a ten-year, competitive, matching-grant program in the NSF, funded at \$500 million per year. We support that recommendation. We further believe that the problem should not be assigned to the Federal government or the Foundation alone for solution. Similar programs are needed in the National Institutes of Health and the other research agencies. In addition, all Federal funds provided for facilities ought to leverage state and institutional funds. Our experience of the 1960s, when NSF and other agencies last had competitive facilities programs, showed that every federal dollar can leverage additional funds. In fact, the NSF successfully leveraged its previous facilities investments by better than two to one. We believe that earlier experience can be repeated, provided NSF and other research agencies provide leadership by establishing competitive, merit-based facilities programs.

New authorizing legislation is required. We hope, therefore, that this Committee will join with Rep. Robert Roe and his colleagues on the House Committee on Science, Space and Technology, who recently introduced H.R. 1905, the "University Research Facilities Revitalization Act of 1987," in developing legislation along the lines recommended by the White House Science Council. The members of the AAU have unanimously endorsed the general approach of H.R. 1905. We would welcome an opportunity to work with this Committee and others in the Senate in formulating a companion proposal.

Conclusion

Thank you for the opportunity to share these views with you. I will be pleased to respond to your questions.

Senator KERRY. Thank you very much, Mr. Rosenzweig, for the endorsement of that concept.

I am going to turn to my colleague for the leading round on this go-round. Senator Pressler?

Senator PRESSLER. Thank you very much.

I would like to just take a broad look at science policy in the United States, and first of all, for any member of the panel, does NSF need any additional programs to broaden the base of scientific research and scientific manpower in the United States? Which programs would they be that you would give the highest priority to?

Dr. WIDNALL. Well, let me try to respond to that.

I view NSF as being an extraordinarily complex agency. The NSF certainly has shown no inability to start new programs. In some sense I really believe that almost anything that someone wanted to do could be done under a current program. So, I would not see the need for starting any new programs.

Mr. WEINERT. I would certainly second that. I think what we need is a great deal more devoted to some of the current programs that we all acknowledge are mere tokens. And the curriculum development in engineering initiative of \$5 million in this budget is just a small start to a very big subject. The whole business of laboratory and computer equipment—there is a significant amount of money from NSF going to those areas, but a great deal more could be devoted.

I think the program structure within the NSF is broad enough. I think what we need is a great deal more commitment in terms of resources to expand those programs.

Dr. WAUGH. Senator Pressler, the major policy change needed I would submit may have already taken place by incorporation of engineering into the fundamental mission statement of the Foundation. And the ability of the Foundation given that mission statement change to change has already come forth. The restructuring of the engineering directorate, for example, has been very dramatic and very responsive. It is not clear that there is a fundamental policy change needed. Evolutionary changes will continue to come.

Dr. MOORE. I essentially agree with my colleagues. The one comment I would like to add to that though is that as I had mentioned in my testimony, I spend about half my time in Europe, and I think that we are underestimating the difficulties that we have with our facilities in this country. In comparison between the University of Stockholm and many of the universities that I visit in this country is striking. The facilities at the University of Stockholm are usually of the very latest type.

Dr. ROSENZWEIG. I would add to that only that the one program area which the Foundation is not now engaged in a systematic and significant manner is facilities support. That is the one that I would believe needs to be added for the Foundation to complete its full role in support of science and technology.

Senator PRESSLER. Well, as Dr. Widnall said, this is a terribly complex agency and issue.

Which other country in the world would do a better job of its NSF type function? Would there be any other country that you would cite as a model? Or do we do about as well as any country?

Dr. ROSENZWEIG. None, categorically. We are the model.

Senator PRESSLER. We're the model.

Dr. MOORE. All of the Europeans that I know, the Japanese, they look at our peer review system with great admiration.

Senator PRESSLER. The Japanese do?

Dr. MOORE. Yes.

Senator PRESSLER. And have they duplicated it?

Dr. MOORE. Well, it is a very difficult, completely different type of operation, much more top-down management. The peers do not have the same type of evaluative control that they have at the Foundation.

Senator PRESSLER. And how do the Japanese do so well?

Dr. MOORE. I think that we have actually seen some rather interesting comments about the Japanese themselves. And looking at what they have done—they have tended to have rather focused programs. They do not have the breadth that we have in our programs.

And they perhaps—I do not have the data to support this, but it is just my opinion. They are very good at taking technology and turning it into something that is used in the marketplace. There is a great deal of difference between taking technology and turning it into a product than there is in actually devising the new technologies or the new science.

Mr. WEINERT. I would certainly like to emphasize they have done well. They have done well in a very specific area as has been pointed out. I do not think we take second seat to anyone in the generation of new scientific knowledge, new engineering and technology. I think where we have fallen down is in the ability to convert some of that directly to competitive products in the marketplace.

Dr. WAUGH. Given the culture, the governmental, the historical values that we bring, I would agree with the others that our National Science Foundation is the appropriate approach. There are other countries that have national universities that are funded differently than ours. The government frequently controls the mission standards, and the science students, and at the same time limits those students to the options available to them as to what they may study. There may be different funding mechanisms. They may even be appropriate to their historical and cultural background. But if you make those comparisons with countries that share our value system, the, our National Science Foundation does the job as well or better than any.

Senator PRESSLER. I guess we would have to say that it is not the National Science Foundation's job to implement our research necessarily. It might be that other countries benefit from our research. Maybe in some ways the Japanese take our research and implement it better than we do. Of course, that would not be the fault of the NSF.

Let me ask you all this. As research becomes more expensive and dependent of previous research, how do we avoid concentrating research funds at only a few institutions?

Dr. WIDNALL. Well, it seems to me that some of those ideas were discussed this morning. I think it is important for individual universities to target areas in which they can achieve some preeminence rather than to spread resources sort of very thinly across the entire sweep of fields of science and engineering. I think of universities that have made sort of major reputations in optics which was

perhaps a neglected discipline in many of the major universities for many years and has now become an extremely important subject of electromechanical engineering which fell between the disciplines in some major universities, taken up as a topic by a few universities. And they can come to preeminence in those areas. Catalysis. I mean there are really a very large number of areas in science and engineering which have particular relevance to industry which can be targeted by individual universities and gone after to achieve preeminence. But I do not think it possible for every university to duplicate everything they see in other universities that they might wish to emulate.

Dr. WAUGH. Senator Pressler, my State like yours was one of the have-not States. We were a participant in the EPSCoR program and a successful participant. I would suggest, however, that as the dependence of the economy and of the national well-being on technology and science has grown, so has the ability of some of these so-called second-tier schools in States like South Dakota and South Carolina.

And if the country is to take best advantage of that growth, there must also be a corresponding growth in the commitment of resources to enable them to develop. If you increase the quality of the schools in the second-tier States, you must also increase the availability of funds to support that quality or it will not sustain itself.

Senator PRESSLER. Well, I think South Carolina has done a good job. You know, in South Dakota we just have the property tax, and our State legislature has been hard-pressed for funds. How did you do it in South Carolina? I think South Carolina is a model. So, was it something your state did?

And let me say I am honored to know—one of my classmates was Phil Lader who was president of one of your colleges, and I got an honorary doctorate from a South Carolina University a couple years ago which I probably have in my office.

But I have been very intrigued with what education has done there. And how did you—could you just tell us how you did it?

Dr. WAUGH. I am not used to being referred to as a representative of a model state, but I—

Senator PRESSLER. Well, in increasing the—

Dr. WAUGH. The EPSCoR monies were, in fact, matched by monies from the State of South Carolina and within the participating universities, primarily Clemson University and my own. A rearranging of priorities and internal reallocations of funds were a significant part of making the EPSCoR program successful.

I must admit, however, that we also in my own case have been the beneficiary of some of the direct—

Senator PRESSLER. I cannot quite hear.

Dr. WAUGH [continuing]. Congressional appropriations.

Senator PRESSLER. South Carolina. Yes, okay. Yes, if you could submit in more detail for the record some of the activities of South Carolina in what I think is a very model increase, that would be very useful.

I will ask one last question, unless somebody else wants to respond to this particular question, to the group. What should NSF

do to interest more young people in pursuing science and engineering careers?

Dr. WIDNALL. Let me speak to that one. Improve the quality of pre-college science and math education. I was shocked—

Senator PRESSLER. That is high school.

Dr. WIDNALL. High school. I was shocked the other day to read an article that indicates that our students scored very far from the top in international tests on science. I knew we scored in a mediocre way on international tests on mathematics, but I was really shocked to see our performance on science tests. I think that it says something about the motivation of our young people for careers in science, that they are not getting in there and working hard in those areas. And I think that is something we should address.

Senator KERRY. How do we do that? I mean, how does the Federal Government? Are we going to change the role of the Federal relationship? Are we going to do it by incentives, by grants?

Dr. WIDNALL. If we are talking about the NSF budget, I think NSF can at most be catalytic. I think they can figure out innovative ways to involve universities and local school districts in model programs, curriculum development, maybe some things to do with new ways of using technology to improve both the quality and the cost effectiveness of the educational process. So, I think that there really are a variety of things that NSF could do. Its role will always be catalytic. As you know, there is a great deal going on across the country, the states, the governors. It is really a very large system. NSF's role is only going to be catalytic.

Senator KERRY. I did not mean to interrupt my colleague here. I'm very sorry.

Senator PRESSLER. That's all right. Well, having a 16 year old teenager in our house, I am sort of retaking biology and physics and finding it a lot more fun this time.

But do we have a drop-off of people—physics, for example, which I think is just a basic—I think you have got to have some mathematics to be able to understand it. But are we dropping off in the teaching of high school physics? Of course, you got to have trig I guess before calculus.

Dr. WIDNALL. Well, let me indicate an even more worrisome—if we stayed even with what we are doing now in the high schools, the demographic factors are going to say that the number of—if the people choose engineering and science at the same rate they have done in the past, demography is going to hurt us, and the number is going to drop down by some 30 percent as we move in, say, the next 10, 15 years in the number of young people just because of demography. So, we cannot even afford to stay even. We have to really move ahead. We have to improve what we are doing so that a larger percentage of our young people choose careers in science and engineering.

And this gives me an opportunity to say something that I was not able to say in my testimony for lack of time. We have to target additional groups. And I am speaking here of women and minorities. We have to figure out ways to tap the potential of groups which hithertofore have not felt a part of the science and engineering community.

Mr. WEINERT. I would like to just add to those comments that, first of all, I think we have to start perhaps before high school. You have focused on high school. And I really think that the kind of excitement and the kind of interest that we are talking about is going to really have to start in the Kindergarten through 6 period. Certainly you cannot wait till high school because the choices that the youngsters must make in the 9th and 10th grade concerning the subjects they are going to take are going to be key to their ability to be ready to go into engineering and science in college. So, they have got to be motivated before they get into the high school course selection process.

Then you said how can NSF help. Well, in addition to just being a general catalyst, there are program supports that they could provide and are providing for teachers now. But in addition to that, we perhaps ought to have a really number one national design competition for high school students that excites and gets all the kids of the country involved in some kind of a design project where there is a national finals and a lot of hoopla and rewards and publicity—in other words, excitement. And I think that funding from the National Science Foundation to get such programs off the ground, to create these kinds of national events and competitions that create excitement is a very direct and definite role for the National Science Foundation.

Senator PRESSLER. Thank you.

Senator KERRY. We are going to have to wind up. I apologize about this. No one could have anticipated we would have three votes, but we are in the middle of a vote, and I am going to have to run to this one again. I think we are going to get back-ended on it in terms of the total time here.

But let me just ask very quickly a question for all you. You know, you have all voiced strong support for basic research, and obviously we know we need to do that. We have put a lot of money into it. We win Nobel Prizes. We come up with new innovations. But the Japanese get the profits, and they excel in manufacturing and in commercializing new discoveries.

So, with all the talent in our universities and all the money invested, why are we having so much trouble in terms of our technology problems, conversion to the marketplace, et cetera? Dr. Widnall, do you want to start with that?

Dr. WIDNALL. Let me just take the issue of super computers because I think that is a technology that we should target. I think it is clear that we are a world leader in that market. I believe we are a world leader perhaps only because of things that the U.S. government did. NSF's super computer program placed super computers in the universities. NASA, DOD, the other agencies bought, ordered and used super computers to the point where our own fledgling industry, which certainly was fledgling at the beginning, is growing to be healthy.

Now, that industry right now would probably say that they could not afford to give universities the traditional 80 percent discount. That really is the way the computer industry has put computers in universities. The Japanese are giving their universities 80 percent discounts on super computers to put them in the universities. They have recognized the universities as a very important test bed for

super computers. They are even giving discount to our universities. There is an agreement with a consortium down in Texas to place a Japanese super computer there at an 80 percent discount in return for the software, which is the area that the Japanese are behind in.

So, I think this is a microcosm of how the Japanese have targeted particular industries and have priced and marketed in a way that American industry was not willing to do. And I think in the super computer industry we have a chance. We have a chance because of the prior efforts of NSF, NASA, DOD. I happen to believe that there is an insatiable world demand for super computers and that this is an area we simply have to stay in, and that the government, in fact, has done a lot to stimulate that area and has to continue to do it.

I think that is where the Japanese have really led. I don't think it has been in actually the transfer of technology into products as much as it has been the marketing, the pricing, the competitive pricing of those products in order to win a market share and essentially establish a situation where you are really the only person who could afford to make such a product.

Senator KERRY. Is there anybody who disagrees and wants to add anything?

Mr. WEINERT. Well, I would just like to add I guess, not disagree although maybe a slight disagreement.

I do think transfer of technology, which is a subject we have not talked about, is an element particularly when it deals with medium and small size businesses and industries. And I do think that we need to pay more attention about how to get research results into the hands of people who might make constructive and productive use out of them.

And in the case of medium and small industries, it may even go beyond that. We may need a Federal commitment to provide some kind of seed money to help get those results over into the industry so that they can begin the process of product development because venture capital to take that kind of a risk for a medium or a small industry is not readily available. And these are areas that I think we need to look at. Let's make sure the knowledge that we have is available to all the people who might wish to apply it. And in the case of those small and medium sized industries, let's figure out a way to help them take the leap of grabbing that knowledge and trying to convert it into commercially competitive products. And that is going to require some outside help. Not many venture capitalists are going to take that on.

Dr. WAUGH. As Senator Hollings noted in the introduction to his recently introduced bill, within days of the announcement of breakthroughs in superconductivity in American universities, the Japanese had already formed an organization to move it to the marketplace consisting of government, industry and university groups. We perhaps lack the appropriate mechanisms to do some of those things. They are more focused on moving things to the marketplace than we are at times.

Dr. MOORE. I think there is one other aspect that we have touched upon earlier in other contexts, and that is relative to the Japanese society, we are a technologically ignorant nation in terms of the body politic. And this ties really to the grammar school and

high school education. If the people who become marketers are more aware of the technology and the technological and scientific issues associate with the products that they hope to market, I think we would see better marketing done in this country.

Senator KERRY. That is an interesting concept. Just hold on one second, if I may.

[Pause.]

I am very apologetic here, but we are going to run into a time problem in my getting back which I am not happy about at all because I just feel this is incomplete. And it is very incomplete from my perspective because I have a table full of questions here that I want to ask.

And it is just not satisfactory from my perspective, but it is where we are. And I hope you will understand that.

Let me just say before I run out of here, I really want to reemphasize that your testimony today is terribly important. I am sorry we cannot explore it more. I wanted to find out more about the current relationship in terms of engineers and the NSF, and Dr. Rosenzweig, I wanted to ask you and will ask you some sort of larger questions about the competitiveness issue and where we should be moving and why we are having some of the difficulties to pick up on what Dr. Widnall said.

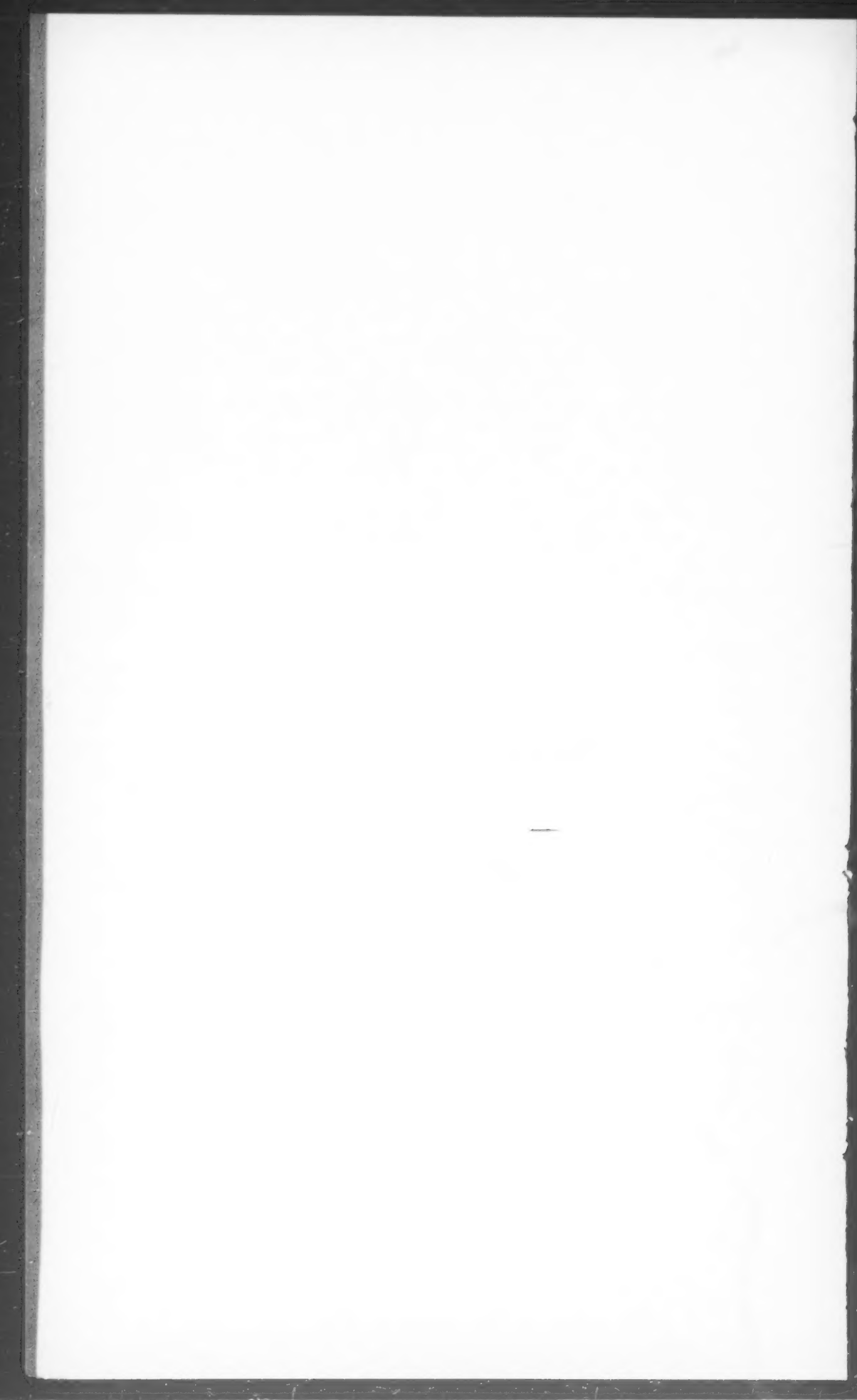
I just think you hit the nail on the head at the end. We are not mobilized, and part of the issue here is the question of whether or not our system does or does not need some major changes. A kick in the rear end or something to understand it cannot operate as usual and respond. And I think that is clear.

So, I think we are on the threshold and I am sure that over the next four and five years, as the politics of the country change and perhaps—well, no matter what administration—we may see some significant changes in how we are going to approach this and deal with it. But I think your contributions are terribly important. And I think this initial dialogue is a very, very important one in that context.

So, I thank you for sharing your thoughts and experience with us. And again, my apologies on behalf of the committee and myself for the compressed nature and the interruptions with which have lived. But I know that all of you have ongoing relationships here, and you know this is not the end nor even the beginning. I look forward to working with you myself over the next days and months. Thank you all very, very much. I appreciate it.

The hearing is adjourned.

[Whereupon, at 12:39 p.m. the subcommittee was adjourned.]



ADDITIONAL ARTICLES, LETTERS, AND STATEMENTS

AAES

AMERICAN ASSOCIATION OF ENGINEERING SOCIETIES

415 SECOND STREET, NE • SUITE 200 • WASHINGTON, DC 20002 • (202) 546-2237

May 26, 1987

The Honorable Donald W. Riegle, Jr.
Chairman
Subcommittee on Science, Technology, and Space
Committee on Commerce, Science, and Transportation
United States Senate
SH-427 Hart Senate Office Building
Washington, DC 20510

Dear Mr. Chairman:

I am pleased to present this statement on behalf of the American Association of Engineering Societies (AAES) regarding the engineering-related activities in the FY 1988 budget of the National Science Foundation. AAES member societies represent more than 500,000 engineers in industry, academia and government; attached to our overall statement is a list of participating societies, as well as specific statements of five of these societies on the NSF budget.

The economic health and vitality of the United States, especially in areas of international competitiveness, is a major national priority of this decade. Historically, technological breakthroughs have been a key factor in increasing U.S. economic competitiveness and raising the standard of living. The recent decline in our economic competitiveness and quality of life is not only of great concern but also points to the need for refocused attention on our technological research and educational programs. A significant increase in the resources directed toward engineering research and education will contribute directly to technological development and economic growth at home, as well as U.S. competitiveness abroad.

Engineering is the bridge from basic scientific research to useful applications that can be developed and commercialized by our nation's industries. To compete successfully against other industrial nations we must invest in basic generic engineering research to provide the infrastructure and talent that will allow the nation to move innovative ideas rapidly into the marketplace. Experience over the past decade has clearly shown that a major reason for the success of our international competitiveness can be directly tied to the ability to move basic scientific findings rapidly into commercial applications. Substantial increases in funding for the NSF Engineering Directorate can bring about fundamental changes in the pace of our technological development, increasing our ability to compete and substantially improve our creativity through basic, cross-disciplinary and interdisciplinary research.

We strongly support the Foundation's proposed 23 percent increase in the Computer and Information Science and Engineering (CISE) Directorate budget, and applaud NSF's two-pronged initiative to support both research into the fundamental understanding of computer and information science and engineering, as well as the expansion of participation in the availability of advanced computing systems.

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The Honorable Donald W. Riegle, Jr.
May 26, 1987
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Continued support for NSF precollege mathematics and science programs is vital to the health of engineering research and higher education. Additionally, expansion of graduate programs at NSF forms another key link in the system. Creation of 200 additional graduate fellowships and 200 new Presidential Young Investigator awards, along with expansion of engineering initiation awards for young researchers, are the types of incentives that can help keep promising young graduate students in academe so they can become future faculty.

Of special significance to the engineering community is the Foundation's proposed initiative in undergraduate education, which is designed to improve undergraduate engineering curricula and faculty development, as well as expand educational instrumentation and undergraduate research programs. Since the 1970's, undergraduate education has barely been addressed at the Foundation; it is important that new undergraduate programs be developed to reverse this unhealthy situation.

We commend and share the Administration's commitment to substantially increase the NSF budget over five years. Historically, technological breakthroughs have been a key factor in increasing U.S. economic competitiveness and raising the standard of living. NSF's continued growth in research and education activities will contribute significantly to technological development and economic growth at home, and U.S. competitiveness abroad. Given the widespread support in Congress for improving U.S. competitiveness, the NSF budget should be viewed as investment in talent and in our future. This \$1.9 billion request, including a \$42 million increase in funding for the Engineering Directorate, though a small fraction of the Federal Government's \$1 trillion budget, is a big cog in the basic research and educational activities which will ultimately fuel the economic engine of the United States. Indeed, NSF support plays a major role in the Federal funding of engineering research. To assure our future position in an ever increasing technologically competitive world, substantial investments will need to be made in engineering research and education. This year's initiative is a good start in revitalizing our technological capability.

I am pleased to have this opportunity to present the views of AAES and respectfully request that this statement and attachments be included in the Subcommittee's written record of hearings on the NSF FY 88 authorization. Thank you.

Sincerely,



Richard W. Karn
Chairman
Board of Governors

Attachments



American Chemical Society

OFFICE OF THE
BOARD OF DIRECTORS

1155 SIXTEENTH STREET, N.W.
WASHINGTON, D.C. 20036
Phone (202) 872-4600

Ernest L. Eliel, Chairman

May 27, 1987

The Honorable Donald W. Riegle, Jr.
Chairman
Subcommittee on Science, Technology, and Space
Committee on Commerce, Science and Transportation
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

Recent events within both the Congress and the Administration have focused on the central role of education and basic research in advancing the economic competitiveness of the United States. As one means to achieve the excellence for which the Nation is striving, the American Chemical Society urges the Subcommittee to support the National Science Foundation's budget at least at the Administration's requested level of funding. Further, Congress must sustain the five-year commitment to double the Foundation's budget by FY 1992 to develop a scientifically educated public and a knowledge base upon which this Nation can build its economic future.

The Society's other major comments concerning the proposed NSF budget are:

- The ACS is pleased that there are proposed increases for the Divisions of Chemistry; Materials Research; and Chemical, Blochemical, and Thermal Engineering.

However, funding of NSF's Chemistry Division has been and, unless action is taken, will continue to be inadequate to exploit the enormous research potential of chemistry as delineated in the National Academy of Sciences/National Research Council Report, Opportunities in Chemistry.

Also, funding levels proposed for NSF's Materials Research and Chemical, Blochemical, and Thermal Engineering Divisions are insufficient to meet the needs of the academic infrastructure in these areas.

- The impact on the health of various scientific fields by the Science and Technology Centers approach as well as other Foundation-wide funding mechanisms should be monitored and evaluated.
- Although the ACS applauds the Foundation's \$115.0 million commitment to the Science and Engineering Education Directorate, the Society also believes that increased support of \$12.0 million over the budget request is urgently needed for enhanced activities. This proposed increase should be new monies added to the FY 1988 budget request for the Foundation.

The American Chemical Society would be pleased to discuss its concerns further with the Subcommittee. The accompanying Appendix outlines the above points in greater detail.

Sincerely yours,

Ernest L. Eliel

THE UNIVERSITY OF MICHIGAN

ANN ARBOR, MICHIGAN 48109

DEPARTMENT OF ANTHROPOLOGY
1054 L. S. A. BLDG.

AREA CODE 313, 764-7274

Senator John Kerry
U.S. Senate
Washington D.C. 20510

June 1, 1987

Dear Senator:

It has been brought to my attention that on May 28th, in a hearing (of the Subcommittee on Science, Technology and Space of the Senate Commerce Committee) concerning the authorization bill for the National Science Foundation for fiscal year 1988, you asked Dr. Eric Block, Director of NSF, about the relevance of anthropology and astronomy to contemporary concerns with the competitiveness of American industry and business. I understand that Dr. Block responded concerning astronomy but not anthropology. I would, therefore, like to give you some idea of how the discipline of anthropology bears upon competitiveness and related issues.

First, it may be useful to note that a popular misconception has it that anthropology is mainly, or even exclusively, concerned with a) forms of humanity ancestral to *Homo sapiens* b) the material remains of extinct societies and what can be inferred from them, and c) the lifeways of the few hunters and gatherers and tribal peoples still tucked away in the world's nooks and crannies. The view that the knowledge produced by anthropology is, by and large, impractical, and that it is much more likely to be encountered in the pages of the National Geographic than the New York Times or Wall Street Journal is also widespread.

Such traditional interests do continue in anthropology and some anthropological knowledge, particularly of the more exotic sort, does reach the public through such magazines as Natural History. But a great majority of anthropologists are concerned with cultural and social (including economic) problems attending ongoing change and development throughout the world of the late twentieth century. They include within their purview not only the "third world," but also the "developed" societies of Europe and contemporary United States.

The institutional organization of the field is of significance in this respect. The American Anthropological Association, with a membership that lies between eight and nine thousand, includes twenty-two specialized constituent societies. One of these, the National Association of Practicing Anthropologists, has 670 members, most of whom are employed in business, industry or government. Another unit, the Society for Medical Anthropology, has 1500 members, most of whom are engaged in work that bears directly or indirectly upon contemporary health problems. The Society for Applied Anthropology and The Washington Association of Practicing Anthropologists, two organizations independent of the American Anthropological Association with combined memberships of

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close to two thousand (many of whom also belong to the AAA), are composed of anthropologists employed by, or engaged in, consulting to, governments, industry, and foundations on all manner of contemporary social, environmental and economic problems. I might also mention that the American Anthropological Association is in the process of establishing a permanent panel on the Anthropology of Business and Industry, which will be concerned, among other things, with the conceptualization of competition and with the factors that have made some companies and some societies (such as Japan and Germany in their different ways) more competitive than others.

I want to assure you that these are not interests to which anthropology has come in the last few years in response to perceived migrations of federal funding for the social sciences to new concerns. They are of much longer standing. Ruth Benedict's classic study of Japanese national character, done during World War II, was very influential in the development of American occupation policy and remains useful to those who must do business with Japan. More recent studies reflect the maturation of the discipline in the context of, and responsive to, changing international political and economic relations. Thomas Rohlen's 1974 study of the organization of a Japanese firm, For Harmony and Strength, has a great deal to say about the competitiveness of Japanese business, as does Ezra F. Vogel's Japan as Number One (1979), the subtitle of which is Lessons for America. I want also to mention Edward T. and Mildred Reed Hall's just published Hidden Differences: Doing Business With the Japanese. The Halls, very senior American Anthropologists, have made one of their main concerns communication, particularly business communication, across the interfaces between different cultures. A previous volume by the Halls on the interface between German and American business people, published in both English and German, has sold tens of thousands of copies. While these books are theoretically interesting and innovative, their readership is predominantly composed of business people. It is of interest in this respect that anthropology forms part of the International Business Curricula at Wharton, in Northwestern's Kellogg School, and at Harvard.

I do not wish to reflect here what seems to have become a national obsession with the Japanese. Anthropological research has been relevant to competition and related matters in other places if not, indeed, globally. At a relatively simple level, with the globalization of the economy, for instance, managers of all sorts have been faced with the difficulties of dealing with the nuances of local markets. Anthropologists already have a substantial record of saving naive Americans from egregious errors on such straightforward matters as product naming and customary ways of dealing with officials, and have helped them understand how and why their staff relations have turned sour. On a less simple level, they have generally attempted, in line with traditional anthropological principles, to contextualize their analyses in consideration of local social and economic conditions with a

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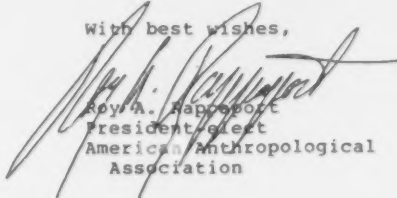
view to avoiding disruptions that may later have to be cured by A.I.D. or other forms of government aid. It is, as we all know, easier to make problems worse than to ameliorate them in this increasingly complex world.

Anthropological studies of organizations and their malfunctioning are also relevant to competitiveness. One anthropological study done for OTA, for instance, showed how an office automation installation which ignored de facto (as opposed to Table of Organization) organization made the operation far less efficient than it had been. I might say, in this regard, that the traditional anthropological method of "participant observation," which involves taking up residence in, and, to the extent possible, participating in the activities of, the unit under study, and relying more heavily, at least in the initial phases, on open-ended interviews and observation than on survey instruments, is especially suited for this type of analysis. It is able to uncover difficulties that apparently more rigorous, but in fact more superficial survey methods cannot.

I would note finally that anthropology has made and continues to make contributions to the understanding of and enhancement of competitiveness (and related matters) not only at the level of empirical studies but at the theoretical level as well. Steve Barnett, an anthropologist who has a regular column in Advertising Age, reconceptualizes for a general public competition itself in his latest piece. Edward and Mildred Hall have developed theories of high and low context communication, and fast and slow media, in their books on international business, and Magorah Maruyama has elaborated his earlier cybernetic approach and applied it to matters directly relevant to competition in his article Experience Looping, Design Looping and Concept Crossing: The Key to Successful Product Invention, Development and Adaptation, in the journal Futures, August 1985. My own work on the structural characteristics of maladaptation in social systems bears upon the topic, and a range of specialists outside as well as inside anthropology have drawn upon anthropologist Gregory Bateson's discussions of the logical types of learning in their analyses of organizational competitiveness and impedences to competitiveness.

It has hardly been possible to do more than touch upon anthropology's relevance to competitiveness in this letter. Let me assure you, however, that I, and my association, stand ready to respond further, if it would be useful to you, and to be of assistance in whatever ways we can.

With best wishes,



Roy A. Rappaport
President-elect
American Anthropological
Association

STATEMENT OF DR. PAUL G. GASSMAN, COUNCIL FOR CHEMICAL RESEARCH

Mr. Chairman and Members of the Committee:

I am Paul Gassman, Professor of Chemistry at the University of Minnesota and the current Chairman of the Council for Chemical Research. It is a privilege to provide testimony to this distinguished Committee on behalf of the Council.

THE COUNCIL FOR CHEMICAL RESEARCH

The Council for Chemical Research was founded 8 years ago. We have worked to build the academic and industrial base for U.S. competitiveness, by strengthening the interactions between academia and industry and by improving support for basic research in chemistry and chemical engineering. CCR's members are the 150 universities where nearly all the U.S. academic research in these fields is done, and the forty major companies which carry out the bulk of the corresponding industrial research.

One measure of the Council's success is that industrial support for academic research in our fields has been increased by a factor of more than three in recent years. But private funding cannot attain anywhere near the necessary level of funding of longterm basic research in chemistry and chemical engineering, which is done mostly at universities. The Federal role in funding these central disciplines is a key factor in the remarkable performance of the chemical industry, which still accounts for a net positive contribution of over \$7 billion to the U.S. international trade balance.

INTERNATIONAL COMPETITIVENESS

The word, "competitiveness" has achieved wide currency, and properly so. It is used in different ways. One meaning is "enhanced quality and productivity."

In the light of that meaning, chemistry and chemical technology can be seen to be uniquely valuable. Largely, this uniqueness arises from the fact that chemistry is the central science of atoms and the molecules formed from them. Atoms and molecules make up nearly all matter on earth. Chemists and chemical engineers study how molecules are made, how they are transformed into valuable new products and materials, and how they can be used safely to improve the quality of life for all humankind.

Chemistry has a central role in the economy, national well-being, and security. The Chemicals and Allied Products industry employs more than a million people and makes annual shipments totalling about \$175 billion. There are more chemists in U.S. industry, contributing to its success, than all other kinds of scientist combined (not counting engineers). Some 40% of the GNP is directly or indirectly derived from chemistry (including food and energy).

Chemistry and chemical engineering also play a central role in other high technology disciplines, by providing techniques, basic knowledge and materials to fields as widely different as biotechnology, medicine, energy, and computer technology, which are themselves key arenas of the competitiveness struggle. An example: the recent astonishing advances in superconductivity (not to be confused with the proposed superconducting super collider) depend heavily on knowledge and techniques of inorganic and physical chemistry.

NEW OPPORTUNITIES

In these tough budget times it is necessary to weigh priorities more stringently than ever. Discoveries and inventions, of course, cannot be scheduled, and the return on investment in science and engineering is never fully predictable. But if one looks at the record, and then at the opportunities spelled out in a recent Academy report¹, chemistry and chemical engineering are a standout. The experts who made that study were very impressed by the accomplishments of recent years, and the anticipated discoveries they saw on the frontiers. They faced their colleagues and bravely named priorities among chemistry's

1. "Opportunities in Chemistry," National Academy of Sciences, 1985.

subdisciplines. (That they did not, then, call out superconductivity proves the importance of the unanticipated result, and thus of flexibility in supporting research.)

Two things excited those experts: vastly improved levels of understanding, and the arsenal of newly available tools -- highly sophisticated instruments -- which allow us to explore at the molecular level problems that were previously intractable. Thus they singled out as especially fertile the areas of chemical kinetics, chemical theory, catalysis, materials, synthesis and analytical methods. These are the very areas emphasized in the NSF Chemistry Division's reshaped program.

The NSF's Chemistry Division is plainly working hard for balance in serving its responsibilities: the vigor of investigations carried out by individual scientists, and participation in the Foundation-wide initiatives in computational science and engineering, improvement of the science base through human resources, and improvement of undergraduate education.

They are also wisely proposing to increase funding in the chemical underpinnings of biotechnology and the chemistry of interfaces, both areas of collaboration with other parts of the Foundation.

It is clear, however, that the level of funding of the Chemistry Division's programs does not come near allowing realistic exploiting of its valid opportunities to serve the economy and our competitiveness, either in the Foundation-wide initiatives or in the priority areas spelled out in the Academy report.

Other nations, in Europe and the Far East, are making national commitments to advancing the importance and uses of chemical science and technology in their industries and economies. If we fail to keep pace and to expand our commitment to chemistry in both research and education, we risk losing our leadership in these fields, as problems in steel and electronics have taught us. We have learned that the report, "Opportunities in Chemistry," is being studied very seriously in those other nations.

EDUCATION OF NEW SCIENTISTS AND ENGINEERS, AND THE PUBLIC

For this country to regain momentum at home and in the international marketplace, certain steps are essential. Two of these go together: we must improve both the funding of basic research and the flow of trained scientists and engineers.

Both of these require better education. First, improved research funding ultimately depends on a better-informed electorate.

Second, an improved flow of people trained for careers in science and engineering needs updated and more attractive courses at all educational levels.

It is therefore somewhat reassuring, though we believe not adequate to the seriousness of the situation, that the Foundation proposes a 16% increase in Science and Engineering Education, since that program addresses both needs: education of students who are aiming at careers in science, engineering and mathematics, and students who have other objectives.

With its influence on universities, industry and business, and its awareness of the trends in science, mathematics and engineering, the NSF is the only agency capable of effectively shaping education in these fields, all the way from early grade school years through high school, college and graduate study.

THE COUNCIL'S RECOMMENDATIONS

With the above background, having in mind the absolutely vital needs of the nation's future both early and longterm, the Council for Chemical Research strongly recommends:

- o In order to seize the new opportunities offered by the proven field of chemical technology, the Foundation's budget should be augmented in FY 1988 by \$10 million in order to achieve a 20% increase in funding of programs of the Chemistry Division, especially as they pertain to single-investigator projects.
- o The Foundation's budget should be augmented in FY 1988 by another \$10 million in order to achieve a 25% increase in Science and Engineering Education.

Mr. Chairman and Members of the Committee, we of the Council for Chemical Research thank you for this opportunity to offer testimony on this vitally important subject.

STATEMENT OF HOWARD J. SILVER, ASSOCIATE DIRECTOR FOR GOVERNMENT RELATIONS,
CONSORTIUM OF SOCIAL SCIENCE ASSOCIATIONS (COSSA)

The Consortium of Social Science Associations (COSSA) represents more than 185,000 American scientists across the full range of the social and behavioral sciences disciplines. It functions as a bridge between the research world and the Washington community. A list of COSSA Members, Affiliates, and Contributors is attached.

COSSA would like to take this opportunity to express our appreciation to the Subcommittee for its past strong support for our disciplines at the National Science Foundation. What follows are our comments on the proposed FY 1988 budget for the NSF and some of the issues raised by that budget.

We strongly support the proposed overall increase of 16.5% in the FY 1988 budget and the proposed doubling of the Foundation's resources by 1992. In this era of budgetary restraint, the strong commitment of the administration to invest in this nation's scientific endeavors reflects an understanding of the importance of basic research to America's future as a great nation. Reducing that commitment will decrease the nation's ability to compete. We urge the Congress to accept the full increase.

The 16.2% increase for Research and Related Activities is also welcome. We strongly urge the maintenance of that increase during the Subcommittee's deliberations. The 13% increase for the Social and Economic Division and the 12% increase for the behavioral programs of the Behavioral and Neural Sciences Division reflect continued NSF support for these programs. These increases will finally return the social and behavioral science programs to their FY 1980 levels in constant dollars.

While it is long past time for this level to be reached, it is no longer a sufficient goal. In FY 1981 President Carter's last budget for NSF requested \$1.15 billion. It included \$40 million for social and economic science and \$39.5 million for behavioral and neural sciences. In FY 1988 the total NSF budget request is \$1.89 billion. Yet the request for social and economic science programs is only \$36.0 million and for behavioral science programs is only \$25.8 million. Thus, while funding for NSF has increased significantly in the past eight years, the share of those funds going to social and behavioral science research has decreased. COSSA believes that the Subcommittee should increase funding so that 5% of the Research and Related Activities budget goes to social and behavioral science research. This would mean adding \$14 million to the FY 1988 proposed funding. We believe this is a justifiable goal given the intellectual vitality and ferment in these sciences and their importance to the nation.

The release later this year of the report of the National Research Council's 10 Year Outlook Study for the social and behavioral sciences will provide a significant picture of the vitality, ferment and contributions of these disciplines. Although not meant to be a comprehensive analysis it will indicate the challenges and opportunities for researchers to develop their work in multi-disciplinary fields and activities. We believe the Subcommittee should pay close attention to this valuable document.

The emphasis on multidisciplinary activity is also reflected in the proposed FY 1988 NSF budget. The inclusion of the social and behavioral sciences in the Foundation's proposal for science and technology centers is appropriate. The proposed National Geographic Information and Analysis Center (NGIAC) will provide greater access to the products of digital remote sensing, geographic information systems, computer cartography, and computer graphics, which will form the basis for major advances in geographical analysis, spatial statistics and expert systems. The enhanced information portrayal and decision making capacities resulting from such theoretical advances will enable society more effectively to resolve the complex environmental and social issues the nation faces now and in the future. This center will involve expertise in disciplines including: geography, information science, computer graphics, political science, remote sensing, risk analysis and many others. Commercial vendors, government agencies, and research universities will share in the services that will be provided by the NGIAC.

The Decision, Risk, and Management Science Program (DRMS) is also strengthening its efforts to encourage collaborative interdisciplinary research across the decision sciences. It too is moving to accept multi-year, multi-investigator proposals for programs of research integrating research strategies and disciplinary perspectives. Three broad problem areas are suggested for exploration: 1) risk perception, communication and management; 2) group decision making; and 3) artificial intelligence approaches to problem structuring and model building for decision support. Here too the number of disciplines involved is large: from artificial intelligence and expert systems to political science, psychology and sociology, to organization design and general systems theory.

In the behavioral sciences a major initiative in the neurobiology of learning and memory will also include increased support for multidisciplinary research teams, and the establishment of a small number of multidisciplinary research and

resource centers. Greater elucidation of the neural structures and processes which underlie the phenomena of learning, memory and information utilization will be the goal of this research.

These three initiatives in geography, decision, risk and management science, and psychobiology are significant indications from NSF that the social and behavioral sciences are an important part of the Foundation's agenda for economic competitiveness. Full support of the NSF's budget request will allow these important research initiatives to go forward.

Concern has been raised in many places about NSF's move to encourage the development of science and technology centers, often perceived at the expense of individual investigator initiated research. COSSA is concerned as well. For many of the social and behavioral science disciplines, the individual investigator remains the key to significant basic scientific research. Yet we can agree with Dr. Harold Shapiro, President of the University of Michigan, who has noted that NSF support of centers "is -- at the current time -- an appropriate strategy to pursue." We also agree with his comment that the "rate of expansion of NSF funding for research centers should be cautious, retain its flexibility, and be the subject of ongoing evaluation." The Subcommittee should keep a wary eye on this situation since the long term effects of support for such centers is at the present unknown.

This would be one of the reasons we would continue to support an ongoing role for the authorization committees in their relationship with NSF. Congressional oversight through the authorization process remains an important check on the agencies of the executive branch. In this year when we celebrate the bicentennial of the Constitution, checks and balances should be reinforced. The Subcommittee should act with caution in evaluating the proposal to move to a five-year authorization for the Foundation.

There are other initiatives for the social and behavioral sciences in the proposed FY 1988 budget that COSSA believes further enhances the necessity to support the proposed increase for NSF. Proposed funding for methodological and research resource development in anthropology will include new emphasis on improving ethnographic research methods and on cross cultural research in this discipline. Analysis of regional databases will provide archaeologists with greater research opportunities.

In political science and economics, increased support for postdoctoral students in political economy will allow for greater study of international economic competitiveness, international trade, and the economic consequences of public sector growth. Continuing support for the three national social science databases remains important. The Panel Study of Income Dynamics, the General Social Survey, and the National Election Studies all provide the data necessary to evaluate the nation's economic, social and political progress. Data collection efforts on Supreme Court decision making should provide students and observers of the court with an important new and comprehensive source of information.

The 16% increase proposed for the Science and Engineering Education Directorate represents a further step in the reinvigoration of that directorate. The commitment of the Foundation to establish a coordinator of undergraduate education is an excellent idea. We also agree with NSF that providing resources for undergraduate education within the disciplines allows for the best integration of research and training for undergraduate social and behavioral scientists. We also applaud the enhanced support for graduate students through increased numbers of fellows and increased stipends that will somewhat mitigate the impact of the Tax Reform Act of 1986.

In the past we have regaled the Subcommittee with lists of significant research accomplishments by social and behavioral science researchers. You have demonstrated time and again your belief that these accomplishments are important to the scientific enterprise within the United States. We ask you to continue that support in the future by giving NSF its full FY 1988 request.

Thank you this opportunity to present our views.

STATEMENT OF LEONARD D. GOODSTEIN, PH.D., EXECUTIVE DIRECTOR, AMERICAN
PSYCHOLOGICAL ASSOCIATION

On behalf of the American Psychological Association, I am pleased to submit our views on appropriations for the National Science Foundation (NSF) for Fiscal Year 1988. APA represents the concerns of more than 87,000 psychologists, many of whom conduct important scientific research with the support of NSF.

In this statement we address specific areas in the Administration's request for FY 1988 appropriations for existing programs and activities and new initiatives within NSF. We also comment on funding proposals of particular concern to behavioral and social scientists.

NSF APPROPRIATIONS FOR FISCAL YEAR 1988

APA appreciates this opportunity to strongly endorse the Administration's proposal to increase the National Science Foundation budget by 16.5 percent for FY 1988 to a total of \$1.89 billion. Moreover, we applaud the President and NSF Director Erich Bloch for their foresight in proposing that the NSF budget be doubled over the next five years to \$3.2 billion in FY 1992. These proposed increases signify a commitment by this Administration to invest in basic scientific research as part of this nation's goal to become more competitive internationally. Such a commitment requires a long-term investment to rebuild our scientific base and to ensure ongoing support for innovative basic scientific research. We urge Congress to support enhanced basic scientific research, which provides the requisite foundation for improving economic growth, productivity and competitiveness, and we encourage the Subcommittee to approve the resources needed to accomplish this goal.

BEHAVIORAL AND SOCIAL SCIENCES

APA commends the Administration for its proposal to increase funding for Research and Related Activities by 16 percent to \$1.64 billion. Of particular interest to APA, are the specific increases targeted for behavioral and social sciences research, adding \$39.3 million to the Biological, Behavioral and Social Sciences (BBS) Directorate. However, funding for the Behavioral and Neural Sciences and the Social and Economic Sciences Divisions is still disproportionately below historical appropriations levels. Although the total NSF budget has been significantly increased over the past few years, spending in the area of behavioral and social sciences has actually diminished in relationship to other research areas. In FY 1980, 8.1 percent of NSF's Research and Related Activities budget was allocated for behavioral and social sciences research, and by FY 1988 it had decreased to only 4.1 percent. APA recommends that Congress target at least 5 percent of Research and Related Activities appropriation towards the behavioral and social sciences.

The behavioral and social sciences have a critical role to play in these efforts to revitalize the nation's economic and technological base. While our international competitors have been quick to recognize these contributions, increases in productivity that could be realized by modifying

organizational structures, personnel policies and decision-making processes have too often been overlooked as critical areas for research in the United States.

While technological advances are important, behavioral and social science research can be even more important in developing new human, social and institutional approaches in revitalizing this nation's industrial base. A few examples follow:

- o Basic research in the social and behavioral sciences plays a much clearer and more consequential role in American institutions and industry than is typically recognized. There is a certain irony in that the findings of this research are perceived by foreign countries to have great export value. For example, it is often suggested in our media that the current superior position occupied by the Japanese steel industry is intimately related to their development of the notion of quality control circles. These control circles rest on two major concepts: a statistically based system of quality control, and participative decision-making. The notion of participative decision-making rests very clearly on basic research in social psychology going back three or four decades.
- o The management structure and processes of American industry are often based on straight-forward behavioral science research. This research includes studies of the relationship of morale and employee satisfaction to productivity, the effects of employee participation in decision-making on productivity, the nature of resistance to change of management practices, employee profit-sharing plans, and the relationship of styles of leadership to group productivity.
- o A global study on the impact of organized programs designed to increase employee productivity in the workplace found that the average worker's productivity did, in fact, increase significantly (Guzzo, Jette and Katzell, *Personnel Psychology*, 1985, Sum. Vol., 38(2), 275-291). This study analyzed the findings of 100 separate studies covering 11 types of psychologically-based organizational interventions. Not all interventions were equally effective. The most powerful strategies, it was found, were in the areas of employee training and goal setting. Surprisingly, supplying employees with increased financial incentives did not reliably lead to increased productivity. The effects of worker incentive programs varied widely the study found, sounding a warning to those who depend solely on increasing compensation to boost productivity.
- o The field of psychology has made great strides in understanding how to maximize productivity, through job-person matching, test validation, and utility analysis. The field is now addressing quality in one's work life, retraining for technological change, and the development of work values and attitudes. Related to these areas of "cutting-edge" psychology are new integrations which are occurring between experimental psychology and human factors research in studying and making recommendations about lighting conditions on roadways, risk-taking under conditions of a poor environment for operating vehicles of various

sorts, the use of special instrument installations in aircraft cockpits, and the exploration of sound levels in human nurseries.

- o The rapid development of information technology, including that involved in the computer sciences, e.g., parallel processing systems, will require major efforts to understand how individuals process and think about information. There is a convergence here of cognitive science and human factors research in the understanding of person-machine interactions.
- o Behavioral and social sciences have contributed directly to management of the research and development process in other sciences. Existing literature has been directly related to the composition of research teams, the organizational structure of research organizations, and the relationship of R&D to other functions of a business firm, such as marketing. In some of the more innovative and productive American firms this knowledge is used routinely to guide research processes, often with direct increases in research productivity.

SCIENCE EDUCATION

APA is also concerned about the future of science education at the precollege, undergraduate, graduate and postdoctoral levels. We recognize that much improvement is needed in our nation's science education activities, and we endorse the House Science, Research and Technology Subcommittee's recommendation to increase funding for the Science and Engineering Education (SEE) Directorate by \$35 million over and above the Administration's \$115 million request. Increased funding in this area is especially critical to restore a priority to science education programs, which were drastically reduced in FY 1982 to \$20.9 million. Without adequately trained scientists and engineers today, the benefits of scientific research will not be realized tomorrow. The importance of the education of our nation's future scientists is properly reflected in NSF's proposed budget.

Additionally, APA is pleased with the Administration's proposal to enhance overall spending for education and human resources activities throughout NSF by \$91 million in the FY 1988 budget request. This increase would raise the total spent on precollege, undergraduate and graduate programs by nearly 50 percent. In keeping with NSF's effort to augment educational support for scientists and engineers, the Administration has proposed to increase spending levels for undergraduate programs by \$38 million and graduate and postdoctoral programs and other related activities by nearly \$53 million. APA is particularly supportive of efforts to increase research experiences at the undergraduate level, enabling psychology students greater opportunities to participate in behavioral science research projects supported by NSF.

NEW INITIATIVES

The benefits of a multidisciplinary approach to advance knowledge and stimulate scientific innovation have been well demonstrated. In order to

accelerate scientific advances to improve our nation's competitive posture, the FY 1988 NSF budget invests significant resources in new science and technology centers. These new multidisciplinary centers will include several centers in the behavioral and social sciences. APA supports the establishment of these new science centers which will expand research in important areas of psychological and social science research. For example, the proposed neurobiology centers will provide research support for the many aspects of learning, memory and cognition.

The neurobiology of learning and memory is fast becoming one of the most active and promising research areas within brain sciences today. For example, important research is being conducted on the disorders of learning and memory, which will form the basis for understanding such illnesses as Parkinson's disease and Alzheimer's disease.

Examples of research on Alzheimer's disease include investigations of the role of catecholamines and neuropeptides as well as cholinergic neurotoxicity in producing Alzheimer-related symptoms. These investigations, in part, have been stimulated by findings that Alzheimer's disease is associated with decreased cholinergic activity which in turn has led to an appreciation of the chemical basis of learning and memory, i.e., how neurotransmitters are involved in learning and memory. Since such studies involve both neurochemistry and behavior, only multidisciplinary research teams can produce the needed studies. Other research has indicated that cortical neurons are the site of pathogenesis in Alzheimer's disease. Furthermore, new drug therapies are being developed for the disease that are based on our understanding of the neural systems that subserve learning and memory.

Given the enormous complexity in conceptualizing the multiple issues and influences related to learning and memory and the neurological processes, APA supports the multidisciplinary center concept, as well as the NSF proposal to expand support for small multidisciplinary research group awards, to facilitate answers to the complex questions on learning and memory.

APA also supports the NSF proposal to develop the National Geographic Information and Analysis Center, which will seek to provide answers to important social and environmental questions based on geographical analysis and spatial statistics.

While APA is encouraged by these initiatives to establish and support new centers in the behavioral and social sciences, we are very concerned about continued support for field-initiated research at NSF. Expanded support for these centers must not drain needed resources from independent-investigator research, which has been the foundation of innovative basic scientific research at NSF. This is particularly important, now that the nation seeks to rebuild economic productivity at home and abroad. APA recommends that support for field-initiated research be maintained and enhanced as funding and resources with NSF are increased.

APA appreciates the Subcommittee's consideration of our comments and recommendations during its deliberations on FY 1988 appropriations for NSF. We strongly believe that behavioral and social science research makes important contributions to the goal of becoming internationally competitive. We commend the Administration for its vision and its conviction that NSF has a major role in supporting basic science and technology. We urge Congress to approve proposed spending increases and program initiatives for NSF in FY 1988.

STATEMENT OF THE ENGINEERING EDUCATION & RESEARCH POLICY COMMITTEE OF THE
AMERICAN SOCIETY OF CIVIL ENGINEERS

The Engineering Education and Research Policy Committee of the American Society of Civil Engineers (ASCE), urges your support for the Administration's \$1.9 billion 1988 budget request for the National Science Foundation (NSF). Understandably, concerns about the federal budget deficit may call into question NSF's proposed \$270 million (17%) increase, however, the nation's commitment to enhancing U.S. competitiveness underscores the importance of preserving this budget increase.

Engineering Directorate funding would rise by \$42 million (or 26%) to a level of \$205 million. ASCE is particularly encouraged by increased support for Mechanics, Structures, and Materials Engineering of \$3.6 million (14%) to a level of \$28.5 million, and by increased funding for Critical Engineering Systems of \$3.2 million (13%) to a total of \$27.7 million. A substantial \$18 million (56%) increase for cross-disciplinary Engineering Research Centers (ERCs) would raise the number of ERCs from 15 to 21. The ERCs expedite the transfer of research results from the lab to America's application in the global market place.

Computer and Information Science and Engineering would be boosted by \$26 million (23%) to a level of \$143 million. In addition, NSF's important commitment to Science and Engineering Education would rise 16 percent, to a level of \$115 million. This funding will support important and expanded education efforts at the precollege, undergraduate, and graduate levels.

We commend and share the Administration's commitment to substantially increase the NSF budget over five years. Historically, technological breakthroughs have been a key factor in increasing U.S. economic competitiveness and raising the standard of living. NSF's growth in research and education activities will contribute significantly to technological development and economic growth at home, and U.S. competitiveness abroad. Given the widespread support in Congress for improving U.S. competitiveness the NSF budget should be viewed as investment in talent, and our future. This \$1.9 billion budget request, though a small fraction of the Federal Government's \$1 trillion budget, is a big cog in the basic research and educational activities which will ultimately fuel the economic engine of the United States. NSF support, indeed, plays a major role in the Federal funding of civil engineering research.

During the 1970's the United States lost ground in the area of economic competitiveness to several industrialized countries. This FY 1988 budget, as part of the five year plan to increase the Engineering Doctorate budget to \$500 million by FY 1992, will help us to begin making up for lost ground. ASCE strongly supports the fiscal 1988 budget request for NSF and urges your approval of it.

STATEMENT OF THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS

It is a pleasure to submit the views of the Institute of Electrical and Electronics Engineers (IEEE) on the proposed budget for the National Science Foundation (NSF), for fiscal year 1988. The IEEE is the world's largest technical professional society, with some 229,000 members in the United States alone. Our membership consists primarily of engineers and scientists in the electrical and computer disciplines, so we have a very great interest in the programs of the NSF.

Administration Proposals

Although this is necessarily a time of austere funding for Federal programs, we believe that the NSF's budget represents the "seedcorn" from which the U.S. economy can grow, by advancing our national strengths in science and technology. Thus we feel that the Administration is fully justified in proposing \$205 million for Computer Science and Engineering, an increase of 23% as part of the overall plan to double the NSF budget in a five-year period. We see these requests as recognition of the key role played by computer and electrical/electronic technologies, now and in the future, in the health of the U.S. economy and our competitive posture internationally.

We fully concur with the proposal to broaden the earlier NSF initiatives on Engineering Research Centers to include Science and Technology Centers, particularly in Computer and Information Sciences and in Material Sciences and Engineering. The proposed new research programs in materials processes and interfaces, cognitive science and architecture, large scale systems engineering, and supercomputer applications are excellent choices as areas that have great potential impact on the future productivity and competitiveness of the nation.

As we have expressed in previous testimony, we recommend an approach which balances support for such centers with support for individual investigators in disciplinary programs, and thus, also balances support for basic and applied research. Thus we also strongly support the proposal to increase the average grant size to individual investigators, largely to correct the decline in real dollars for support of graduate students during the last ten years, and the equally important proposal to increase substantially the funding of Engineering Research Centers, so as to permit these exemplary units to function as originally envisioned. We would like to see further attention paid in future years to basic research in areas, such as telecommunications, which have not received significant increases to date.

IEEE Recommendations: Funding for Small Groups

With respect to the two general styles for supporting research activities, through centers on the one hand and individual investigators on the other, we recommend that a third approach between these two extremes should also be employed by the NSF. Because of the magnitude of funding necessary for research centers, very few can be funded. On the other hand, there are many engineering schools of small to medium size across the country, which taken together contribute a large fraction of the total number of engineering graduates in the United States each year. There is an urgent need to harness this important national resource, if we are to maximize U.S. industrial competitiveness. It is not feasible to operate centers at most of these schools, although many of them have first-class faculty investigators. We suggest that the NSF consider the possibility of initiating a program to support research teams which would not necessarily be either large or cross-disciplinary. Although such teams could, in principle, be supported through either the centers program or the disciplinary programs, it is in fact extremely difficult to compare small group efforts with the other categories. The review process for either of the existing categories tends to eliminate efforts involving three to five investigators. They are clearly too small to qualify as centers, and Disciplinary Program Managers tend to break small team proposals into parts for separate review, which eliminates the synergism available through group efforts.

We would also like to point out that shorter-term, goal oriented research would be one particularly fruitful way of applying such smaller group grants, which could maximize their beneficial impact on productivity in U.S. science and technology. A great deal has been said and written recently about the relatively short-term focus of U.S. industry, which contrasts sharply with the long-term focus of academia. We observe that scientists and engineers from these two critical resource groups in our country are frequently most productive when working together, sharing a focus that is long enough for the results to be competitive internationally, but short enough to give a high likelihood of productive results. Government has had the wisdom to sponsor some such efforts. The NSF Centers are an example, on a larger scale; work sponsored by the Defense Advanced Research Projects Agency (DARPA) is another.

DARPA sponsors a full range of team sizes, and in many cases insists on cooperative university-industry efforts in order to bring together the best of theory and practice.

We would like to encourage the NSF to provide grants to small teams of academics, including some for the purpose of working cooperatively with industry. We believe that engineering faculty members would particularly benefit from the practical experience gained in such work. At the same time a much-needed influence would be applied to U.S. industries, drawing them toward products and manufacturing methods more advanced than their current short planning horizon allows. This approach is consistent with the forward-looking management of research funding which we associate with the NSF, and hope to see it implemented under an expanding budget for the Foundation.

STATEMENT OF THE TASK FORCE ON THE NATIONAL SCIENCE FOUNDATION OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

We appreciate the opportunity to submit our views on the proposed fiscal year 1988 budget of the National Science Foundation. The American Society of Mechanical Engineers (ASME) is an educational, scientific, and charitable society founded over one hundred years ago. Membership in ASME exceeds 114,000 professionals in mechanical engineering. This statement was prepared by a task force of the Council on Education of the American Society of Mechanical Engineers. It represents the considered judgment of the task force, a group of experts in the field, rather than an official position of ASME.

ASME continues its vital interest in the successful implementation of the full range of NSF programs. These comments, however, focus primarily on those aspects of the budget request affecting the contributions of engineering research to national goals.

The task force endorses the Administration's plan to double the NSF budget over the next five years. These proposed increases will help NSF balance its support for programs that foster economic vitality with those that insure the long-term health of basic research. This increased level of support can make a substantial contribution to the nation's economic well-being and national security by insuring continued U.S. pre-eminence in the world-wide market place. We are especially pleased with the foundation's long-term commitment to ensure stability of basic research programs. We are also pleased with the continued efforts to restore support for science and engineering education which was drastically curtailed in the 1982-83 period. However, we strongly urge further strengthening of NSF basic research programs in engineering.

OVERVIEW: NSF ENGINEERING BUDGET

The FY 1988 budget request for the NSF Engineering Directorate is \$205 million. This is an increase of \$42 million or 25.7 percent over the current FY 1987 plan of \$163 million. These proposed increases and the plan to double the NSF engineering budget within the next five years are admirable in the face of the efforts to reduce the deficit and balance the budget. They demonstrate the Administration's commitment to basic engineering research. What justifies these increases is the key role that engineering research plays in improving the quality of life and in the ability of U.S. industry to compete effectively in international markets. Engineering research is a critical component of economic competitiveness.

The U.S. has clearly lost ground in economic competitiveness. A factor contributing to this was our neglect of engineering research during the 1970's. The U.S. is now fourth among industrialized countries behind Japan, West Germany, and France—in the fraction of gross national product invested in civilian research and development. This is a further justification for increasing the NSF engineering budget in FY 1988.

In FY 1985, NSF supported a larger fraction of engineering research at universities and colleges than any other federal agency. Several engineering disciplines rely almost solely on NSF for engineering research support. In FY 1985, NSF supported 91 percent of all federally sponsored engineering research in Civil engineering and 84 percent of all federally sponsored engineering research in Chemical engineering at universities and colleges. More importantly, NSF is the only non-mission agency whose purpose is to support both basic and applied long-term engineering research across a broad spectrum of fields. The results of the research provide a basic knowledge that helps to stimulate technological innovation in the private

sector, which in turn can impact U.S. competitiveness in the international marketplace.

The Engineering Division of NSF has programs in two broad areas, basic or disciplinary engineering research, and more focused or cross-disciplinary engineering research. In FY 1988, 70 percent or \$29.4M of the \$42M increase will be in the focused or cross-disciplinary areas of engineering research. These include the Engineering Research Centers (ERCs), an \$18.5M increase or 44 percent of the total increase; the Emerging Technologies Division, a \$3.7M increase or 9 percent of the total increase; the Critical Engineering Systems Division, a \$3.2M increase or 7.6 percent of the total increase; and the Design, Manufacturing and Computer-Integrated Engineering Division, a \$4.0M increase or 9.5 percent of the total increase.

The basic engineering programs will receive a \$12.6M increase. The Chemical, Biochemical and Thermal Engineering Division is slated for an increase of \$3.1M or 7 percent of the total increase; the Mechanical Structures and Materials Engineering Division, \$3.6M or 8.6 percent of the total increase; and the Electrical, Communications and Systems Engineering Division, \$5.9M or 14 percent of the total increase. It should be noted that even within these divisions, the largest increases are in the more focused or cross-disciplinary programs. For example, the Materials Engineering and Processing Program in the Mechanics, Structures, and Materials Engineering Division is budgeted for a \$1M increase; and the Large Scale Non-Linear Systems Program in the Electrical Communications and Systems Engineering Division is budgeted for a \$2.7M increase.

While it is too early to gauge all the benefits to be derived from multidisciplinary Engineering Research Centers, they have already prompted significant intellectual and financial efforts and cooperation in the academic community, as well as strong financial support from industry. We believe that many exciting projects are being developed within the ERCs which have the potential for major breakthroughs in such areas as telecommunications, robotics, biotechnology, and the development of composite materials. We believe that the current 15 authorized centers merit continued strong support, and that the number could be appropriately expanded in FY 1988 to as many as 21 centers. We, therefore, endorse the Foundation's request for an increase of \$18 million in the ERC program to \$48 million. We hope that the Subcommittee will give this request its fullest consideration.

In addition, we fully support the project growth in funding levels for the cross-disciplinary programs, the Industry/University Cooperative Research Centers (IUCs) and the Presidential Young Investigator (PYI) programs. NSF resources for fundamental engineering research should continue to be managed to ensure that industry is an active partner with universities. The ERC, IUC, and PYI programs are appropriately designed to accomplish this goal. An important and potentially long lasting result is that an industrial commitment to ERCs, IUCs, or PYI encourages industry to commit a larger share of its own resources to applied research and development than might otherwise occur.

While the increases proposed address the needs of the ERCs, the emerging engineering technologies, the critical engineering systems and other more focused or cross-disciplinary programs, there is a need to establish a balance between these programs and the more traditional programs that provide funding of investigators working individually in one of the classical engineering disciplines. The need for this balance is clearly apparent in years of budget cuts. Because the increases in these traditional programs have been less than in the more cross-disciplinary programs, an across the board budget cut has a greater effect.

One way to alleviate the problem would be for the NSF Engineering Directorate to establish more formal mechanisms of interaction and cooperation between the disciplinary and cross-disciplinary programs.

We now move to comments on the specific engineering divisions at NSF.

CHEMICAL, BIOCHEMICAL, AND THERMAL ENGINEERING DIVISION

One continuing objective of the NSF in FY 1988 is "to strengthen multidisciplinary research and training in engineering at universities." In the formation of this Division as part of the NSF re-organization, new and improved symbiotic relationships were created between programs related to chemical, biochemical, and thermal processes. This is particularly true in the Division's Thermal Systems and Engineering Program, which is a merger of previous programs in heat transfer, thermal systems, and combustion. This progress continues and the 1988 budget request continues support of this initiative.

Of the five programs in the Division, the Thermal Systems and Engineering Program remains the largest and most central to *mechanical* engineering education and practice. Approximately 35 percent of the 3,800 mechanical engineering faculty

members in U.S. universities teach and do research in the thermal systems area. Fundamental research in thermal systems impacts on virtually every industry and product—e.g., manufacturing, transportation, health care and human rehabilitation, defense systems, and the supply of energy, materials, and food. The recent Space Shuttle disaster was assessed as a thermal systems problem. The U.S. is rapidly losing still another basic industry—i.e., aluminium production—because insufficient understanding exists on how to solve the thermal systems problems—i.e., how to reduce energy required to produce the aluminum so that the total production cost is competitive with that of competitors in other countries.

Increased understanding of the behavior and operating limits of industrial thermal processes, equipment, and components relates significantly to long-term restoration of the competitive position of U.S. industry to world markets. Clearly, the requested \$8.88 million for the thermal systems portion of this program in FY 1988 is very modest considering the pervasiveness of thermal processes. We also note that while this is above the 1987 current plan, it is below the 1987 budget request. This would be a major concern since heat transfer, which is part of thermal systems program, is key to most of the emerging engineering technologies. For instance, the development of techniques for very rapid cooling, more rapid than ever before believed possible in heavy manufacturing, has been the key for a novel process of connecting rod manufacture recently announced by General Motors. This process is widely considered a major breakthrough in automotive manufacturing. At the other end of the scale, heat transfer is the key to several highly desirable advances in the development of electronic devices.

It is also important to recall that increased progress in this sub-field will contribute to a reduction in energy consumption. This remains a national priority in spite of recent, and surely temporary, relief in energy pressures.

We applaud the indicated new initiatives in thermal processing; the search for new catalysts to replace the platinum group metals; the emphasis on aerosol technologies; and the emphasis on neglected areas of materials science in engineering applications. It is, however, unfortunate to note the required budget reductions in CBTE for 1987, and their subsequent impact on continuing research in these vital areas.

MECHANICS, STRUCTURES, AND MATERIALS ENGINEERING DIVISION

This division supports fundamental research on the behavior, response, and failure of materials, structures, machines, and their components. The objective is to advance the engineering methodology underlying the mechanical, structural, materials processing, manufacturing, and natural resource management and control technologies.

We are pleased to see the proposed \$1 million increase in the materials engineering and processing program. This a priority for ASME. The proposed 14.5 percent increase for this division is essential to maintain the division activities at acceptable levels.

The programs within this division have the potential to have a major impact on the economic competitiveness of the U.S. For example, the Dynamic Systems and Control program can contribute substantially to the long-term restoration of America's world leadership position in the production of machines, processes, structures, vehicles, and other devices. The NSF can be a catalyst in supporting much needed fundamental and generic research in the vital area of dynamic systems and control of mechanical systems. Yet, the level of funding projected for this program in FY 1988 is considerably less than required, considering its broad scope, integrative nature and relevance to the critical mechanical and manufacturing industries of the nation. The funding level for this program should be increased at a significantly higher rate over the next several years than has been projected for FY 1988. Otherwise, the urgently needed development of new knowledge and the expansion of the manpower base in the critical field cannot be achieved.

The budget levels for the other programs in this division should also be given priority for further increases. Given that each program has to support a specified number of Presidential Young Investigator Awards, and that the Fluid Dynamics and Hydraulics program supports the largest number of PYIs in the directorate, the funds available for the support of research in some of the programs in this division have not been substantially increasing. Considering the increase in costs of supporting research, it is possible that, if these funding trends continue, the number of investigators and graduate students supported by these programs could be half of their 1984 levels by 1990.

ELECTRICAL, COMMUNICATIONS, AND SYSTEMS ENGINEERING DIVISION

This division supports research to develop an engineering knowledge base for the analysis, synthesis, design, and fabrication of materials, components, devices, systems, and phenomena that involve electrical, electronic, electromechanical, or optical technologies. In addition, the Systems/Theory and Operations Research and Large Scale Non-Linear Systems programs are responsible for developing generic principles and methodologies that support the full range of engineering systems.

We are pleased to see proposed substantial increases for some of the programs in this division, particularly for the Solid State and Micro-structures program (16.9 percent), the Instrumentation, Sensing and Measurement program (27.3 percent), and the newly formed Large Scale Non-Linear Systems program (117.4 percent).

Given the budget cuts of previous years, the other programs in this division, even with the proposed 10 percent increase, would be operating at FY 1986 levels.

There is a need to give priority to restoring these programs to acceptable levels.

DESIGN, MANUFACTURING, AND COMPUTER-INTEGRATED ENGINEERING DIVISION

We are pleased to see the proposed increased support of 28.4 percent, from \$14 to \$18 million for manufacturing and related research, which is a major area of emphasis in the ASME technical programs. Unlike the traditional "mature" mechanical engineering related disciplines of thermodynamics, fluid mechanics, heat transfer, and solid mechanics, the disciplines encompassed by design, manufacturing and computer engineering are only now emerging and being codified. They lack a strong science base, but such a base appears feasible. These "emerging disciplines" provide an integrating framework for the continued significance of the mature mechanical engineering disciplines. Moreover, these emerging disciplines are of vital importance to the international competitive strength of the U.S.

These emerging disciplines have been neglected within the universities so long that major new initiatives are needed to revitalize the related instruction and research programs, and to rebuild the human resource base needed. It is interesting that some university faculty members who formerly worked in the traditional engineering science areas are now migrating to these emerging disciplines. This shift is fortunate, since there will follow a better understanding of the need to focus on fundamental research issues. There appears to be a clear dichotomy between the fundamental and generic research needs that should and will be addressed through the Division's programs, and those that should be addressed by industry and other federal agencies.

In a study of "Research Needs in Mechanical Systems" conducted for the NSF by the ASME, four basic disciplines were identified as being of critical importance to the economic health of the nation: dynamic systems and control, design methodology and interactive computer graphics, machine dynamics, and tribology. In addition, a principal outcome of the study was the recognition that developing national capability in computer-integrated systems and design and implementation is the single most important issue in the field of mechanical systems. On this last point, it is concluded that a major national initiative is needed in computer integration: in design, manufacturing and operations; in intelligent products; in the computer-human interface; and in the processes of education and professional practice. It was recognized that this need goes far beyond the field of mechanical systems and is, in fact, a major national need in all engineering fields. The programs in the new division are structured to address this national need.

The ASME study of Research Needs in Mechanical Systems, and several other NSF supported studies, have had a profound influence on the new structure and mission of the Engineering Directorate. The major recommendations of the ASME study have been fully incorporated. The NSF has been responsive to input from the research community, and quite perceptive of their role in focusing on national priorities. We have recently proposed a similar study of research needs in manufacturing to assist NSF and the Department of Defense in identifying research imperatives with the greatest potential for advancing U.S. technological leadership.

The emergence of the fields of artificial intelligence and expert systems promises to provide the stimulus for greater understanding of design as a process, as well as a guide for development of fundamental axioms for design. The continued development of the tools of geometric modeling, and more generally interactive computer graphics, can potentially revolutionize the way design is done, and the way in which design results are transferred into quality and competitive manufactured products.

The programs in this division support research aimed at developing the base of scientific knowledge needed for rapid advances in design and manufacturing. With-

out such advances, the international competitiveness of U.S. industry will continue to erode, and more basic industries will move offshore.

EMERGING ENGINEERING TECHNOLOGIES DIVISION

The purpose of this division is to support those technological areas that show promise for enhancing, over the long-term, the national economy, employment base, and security, and for which the Nation's universities do not yet have an adequate research and human resources base. The proposed NSF budget incorporates a 23.9 percent increase in FY 1988 funding compared to the current plan for FY 1987. Particularly impressive are the increases in Biotechnology (\$1 million) and the establishment of a new program in Neuro-engineering at a funding level of \$2 million. The programs in Biotechnology, Bioengineering, and Neuroengineering represent in many ways a new frontier and an opportunity for the United States to maintain a position of leadership in an area that may affect very profoundly our future technological strength. The Computational engineering program of this division is an area where foreign competition is becoming stronger; the importance of this field is paramount not only from the point of view of overall technological leadership, but also from the points of view of productivity and of national defense.

We applaud the approach taken in this division, namely to add or substract emerging areas as the need is established. We believe that it is proper for NSF to take a position of leadership in shaping the research direction of the future.

CRITICAL ENGINEERING SYSTEMS

This is a new division with most of the programs formerly in the old Emerging and Critical Engineering division. This division deals with research areas that involve large scale systems in such areas as earthquake hazard mitigation, environmental engineering, systems engineering for large structures, and material and man-made hazard mitigation.

This division has a proposed increase of 12 percent. Given that the actual FY 1987 budget is an 8.2 percent decrease over FY 1986, the proposed increase represents a modest increase for FY 1988.

CROSS DISCIPLINARY RESEARCH

This activity has gained tremendously in importance with the initiation of the NSF Engineering Research (ERC) program. The key role that such centers can play in fostering cross-disciplinary research was clearly defined in the report from the National Academy of Engineering that originally proposed this new approach. Since the inception of this program, 312 ERC proposals have been received from 60 percent of the graduate degree granting engineering schools, showing the strong academic interest in these activities. Even more significant is the partnership that the ERCs have with industry and state governments. These sectors have joined in support of the concept to more than double NSF's annual contribution. This strong support indicates the widely held belief that these centers will contribute significantly to American industrial productivity and international competitiveness.

ASME is firmly committed to encouraging cross-disciplinary research that provides for the involvement of industry, universities, and government. Our new Institute for Innovative Excavation Equipment and Systems, for example, will involve personnel from electrical, civil, mining, computer engineering, mechanical, industrial, and other engineering departments from universities all across the country. Researchers from these departments will work together with personnel from industrial and government laboratories on projects of mutual interest.

We endorse the proposed FY 1988 increase in the Engineering Research Center program of \$18 million.

The remaining activity under the Cross-Disciplinary heading, the Industry/University Research Centers, is projected to increase from \$0.5 million to \$3.5 million.

CONCLUSIONS AND RECOMMENDATIONS

We support the major outlines of the FY 1988 budget for the Engineering Directorate and praise the Foundation's commitment to developing and sustaining a high level of federal support for both engineering research and education. Given the impact that engineering can have on U.S. economic competitiveness and the importance of NSF to many areas of basic and focused engineering research, we feel that it is indeed essential that Congress at least double the Foundation's budget over the next five years.

These budget increases will help NSF balance its support for programs that foster economic vitality with those that ensure the long-term health of basic engineering

research. In particular, the five year plan to more than double the Engineering budget to \$500 million by FY 1992 will provide the necessary funds to restore a proper balance between basic and focused engineering research.

We should point out that as ambitious as these budget increases may seem, they may not be enough. There is much catching up to do in areas that have been neglected for too long. Further, it must be recognized that the five year plan will be difficult to achieve if the Congress does not take the first step toward that goal by approving a significant increase for the FY 1988 budget of the Foundation.

It is our hope that the Subcommittee will see the budget as an important investment in the nation's economic and industrial future, the rewards of which the nation will reap many times over.

STATEMENT OF THE ENGINEERING EDUCATION TASK FORCE

We appreciate this opportunity to share our views on the National Science Foundation budget for Fiscal Year 1988. This statement is being submitted for the record by the Engineering Education Task Force, a multi-society group working together to address major issues in engineering research and education. Member organizations are the American Society for Engineering Education (ASEE) including its Engineering Deans Council, the National Society of Professional Engineers (NSPE), and the National Association of State Universities and Land Grant Colleges (NASULGC).

ASEE is a membership society of more than 10,000 faculty, as well as schools of engineering and engineering-oriented industries. NSPE is a professional society representing 75,000 professional engineers in industry, private practice, government and education. NASULGC is a higher education association whose member colleges and universities educate more than two million of the nation's students.

The Engineering Education Task Force strongly endorses the proposed FY 1988 budget for the National Science Foundation (NSF). We believe the substantial increases proposed for engineering research and education recognize the vital role of the nation's engineering enterprise in strengthening U.S. economic competitiveness and the quality of life. It is the research achievements and education of young engineers and scientists today that will lead the nation into the high technology future of the 21st century. Our comments will focus on the education programs within the Foundation.

NSF Education Programs

Continued support for NSF precollege mathematics and science programs is important to the health of engineering and scientific research and education. Highly motivated, well-prepared students must come out of the high school pipeline or the nation will face a serious shortage of the engineering workforce necessary for the increasing needs of government, industry and academe. NSF precollege programs in recent years have helped spur a nationwide effort to improve precollege mathematics and science. They can inspire such efforts as the MATHCOUNTS program sponsored by NSPE in which seventh and eighth grade students receive coaching and participate in mathematics competitions, and the Junior Engineering Technical Society (JETS) sponsored jointly by ASEE and NSPE.

Expansion of graduate programs at NSF forms another key link in strengthening the engineering education system. Expanding the number of graduate fellowships, Presidential Young Investigator (PYI) awards, and engineering research initiation awards will help more institutions attract, keep and develop promising young engineers as graduate students and faculty members. One of the most serious problems facing schools of engineering today is the shortage of faculty: a 1985 ASEE survey showed an 8.8 percent vacancy rate in *funded* engineering faculty positions. The figure rises to an alarming 19 percent if one considers restoring the faculty-student ratios of the mid-1960's. There are several reasons for the faculty shortage—including higher salaries and better research facilities in industry—but prestigious NSF fellowships and research opportunities offer important incentives for the brightest students to consider academic engineering careers.

The Undergraduate Education Initiative

Of special significance to the engineering community is the Foundation's proposed initiative in undergraduate education. Over the past several years, NSF has maintained strong graduate education programs and since 1983, has considerably upgraded its precollege activities. But since the 1970's, undergraduate education—the vital bridge between high school and graduate study—has been sorely neglected at the Foundation. This new undergraduate initiative will begin to redress that unhealthy situation.

Unlike the scientific disciplines where the principal point of entry into the professions is the doctoral degree, more than two-thirds of the nation's new engineers complete their formal education with the baccalaureate degree. This makes it particularly critical that undergraduate engineering education be first-rate; most engineers do not go to graduate school to learn the technological tools and processes of their profession.

Serious Problem Areas

Partly because of its own success and because of increasing government and industry demand for engineers, the engineering education system is under severe strain. Engineering enrollments have doubled over the past 10 years at the same time that engineering schools have been experiencing serious fiscal constraints. In combination with other factors, this strain on resources has led to—

- serious overcrowding of classrooms with resulting faculty overload, loss of morale and "burnout";

- a severe shortage of engineering faculty, particularly in such areas as electrical and computer engineering. The ASEE 1985 survey showed an 8.8 percent vacancy rate in funded engineering faculty positions, up from 8.5 percent in 1983;

- inability to update curricula to reflect rapidly changing technologies and engineering practice;

- deterioration of laboratory experiences because of obsolete equipment and facilities, along with the rapid pace of change in instrumentation;

- continuing low numbers of U.S. engineering students going on to graduate study and attainment of the Ph.D. The ASEE 1985 survey showed that only 59 percent of engineering graduate students were U.S. citizens; the remaining slots were filled by non-citizens; and

- reduced rate of success for engineering schools in attaining a full six year accreditation rating.

These problem areas have been well-documented in such recent reports as the National Science Board's *Undergraduate Science, Mathematics and Engineering Education* (NSB 86-100) and ASEE's *Quality of Engineering Education*.

The Role of NSF

NSF cannot be expected to address these problems singlehandedly nor to remedy the situation overnight. But what the Foundation can do is what it does best: demonstrate federal leadership in an area of national importance, serve as a catalyst for the best minds in academia to turn their attention to researching and developing solutions to the problems, and leverage resources from industry, state and local governments and academic institutions in a broadly-based, synergistic effort to address the challenge.

We believe NSF's proposed \$68 million program for FY 1988 is an important step in this direction and we applaud the Foundation's foresight and commitment to substantially improving undergraduate engineering and science education.

What Can NSF Do?

Curricula Reexamination.—By providing a nationally competitive, merit-based program of support, NSF can inspire major reexamination of engineering curricula including means of incorporating design, synthesis, computer integration and engineering systems into curricula, as well as finding innovative ways of making teaching more effective and efficient. This can include development of new computer softwares, creation of self-paced learning modules or new instructional technologies for face-to-face and learning at a distance.

Laboratory Redevelopment and Instrumentation.—In recent years, the engineering laboratory experience for both undergraduate and graduate students has deteriorated. In conjunction with curricular redesign, the laboratory experience must be revitalized. Efforts are needed to find cost-effective ways of providing students with hands-on technical experience, including exposure to contemporary engineering practice and today's technologies.

Faculty Development.—A wide variety of NSF-fostered activities could increase the attractiveness of faculty careers and contribute to the lifelong professional development of individual faculty members. The possibilities include new research opportunities not only in technical fields but in engineering teaching and learning, as well as expanded workshops, seminars, sabbatical leaves and faculty networking.

Undergraduate Research.—Opportunities for promising undergraduates to experience first-hand the rewards and challenges of academic research could prove a major new incentive for students to continue on to graduate study and academic careers.

Summary

Through the Foundation's leadership, its role as a catalyst for activity, and its ability to leverage resources, we believe these programs will generate a nationwide effort to revitalize undergraduate science and engineering education. This, in turn, will help ensure the nation sustains the skilled, well-educated and flexible workforce necessary for it to remain competitive in the economic, industrial and national security spheres.

Once again, the Task Force urges you to fully support the FY 1988 budget request of the National Science Foundation. We believe the Foundation's research and education programs—particularly the undergraduate education initiative—represent a sound investment that will benefit the nation both now and in the decades to come.

